GENERAL LIBRARY
UNIV. OF MICH.
OCT 14 1919

Vol. [illegible] AUGUST, 1919 No. 2

1826 **Journal** 1919

of

The Franklin Institute

Devoted to Science and the Mechanic Arts

EDITED BY R. B. OWENS, E.E., M.A., D.Sc., F.R.S.C.

Associate Editors:

BRIG. GEN. JAMES ALLEN
WILDER D. BANCROFT, PH.D.
COL. JOHN J. CARTY, E.D.
ALLERTON S. CUSHMAN, PH.D.
COL A. S. EVE, F.R.S.
W. J. HUMPHREYS, PH.D.
HARRY P. KELLER, PH.D.
A. E. KENNELLY, SC.D.
GAETANO LANZA, C.E.
RALPH MODJESKI, D.ENG.
L. A. OSBORNE, M.E.
ALBERT SAUVEUR, B.S.
EDGAR F. SMITH, PH.D.
MAJ. GEN. GEO. O. SQUIER, PH.D.
C. P. STEINMETZ, PH.D.
S. W. STRATTON, SC.D.
CHIEF CON. D. W. TAYLOR, U. S. N.
S. M. VAUCLAIN, SC.D.
E. S. WOODWARD, PH.D
A. P. ZAHM, PH.D.

Committee on Publications:

GEORGE D. ROSENGARTEN, CHAIRMAN

G. H. CLAMER GEORGE A. HOADLEY W. C. L. EGLIN E. H. SANBORN

CONTENTS

Electrical Treatment of Sewage: The Landreth Direct Oxidation Process . . 157
HENRY JERMAIN MAUDE CREIGHTON AND BENJAMIN FRANKLIN

Some Remarks Concerning the Heat Treatment of Steel and Their Application to the Treatment of Steels Used for Airplane Motors 189
ALBERT SAUVEUR

Gimbal Stabilization 190
V. BUSH

The Photometric Scale 217
HERBERT E. IVES

Development of an Airplane Shock Recorder 237
A. F. ZAHM

Pitch Pockets and Their Relation to the Inspection of Airplane Parts 245
J. R. WATKINS

Recent Progress in the Manufacture of Glasses for Protecting the Eye from Injurious Radiations 255
W. W. COBLENTZ

Notes from the U. S. Bureau of Standards: 263
Some Optical and Photoelectrical Properties of Molybdenite.
A Standardized Method for the Determination of Solidification Points, Especially of Naphthalene and Paraffin.
The Standardization of the Sulphur Boiling Point.
Metallic Coatings for the Rust-proofing of Iron and Steel.
Leakage Resistance of Electric Railway Roadbeds and Its Relation to Electrolysis.
The Constitution of Aluminum and Its Light Alloys with Copper and with Aluminum.

Notes from the U. S. Bureau of Chemistry: 269
The Constitution of Capsaicin, the Pungent Principle of Capsicum.
The Zinc Content of Some Food Products.

Notes from the U. S. Bureau of Mines: 271
Method of Administering Leases of Iron Ore Deposits Belonging to the State of Minnesota.
Electrodeposition of Gold and Silver from Cyanide Solution.
Electric Furnace Laboratory Equipment at Seattle Station, U. S. Bureau of Mines.
Carbon Black from Natural Gas.
Minor Notes.

The Franklin Institute: 279
Library Notes.
Correspondence.

Book Notice 285

Publications Received 285

Current Topics . 187, 188, 198, 216, 236, 244, 253, 254, 261, 262, 268, 270, 278, 286, 287

Announcements . . . . . ii, ix–xiii

Published Monthly by

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, PHILADELPHIA

FIVE DOLLARS PER YEAR (Foreign Postage Additional.) SINGLE NUMBERS, FIFTY CENTS

Entered at the Post Office at Philadelphia, Pa., as second-class matter.

Copyright, 1919, by THE FRANKLIN INSTITUTE

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1919.

INDEX TO ADVERTISERS

PAGE

. iii

. vii

. . . . . Fourth cover page

. xiv

. xv

. iv

. vii

. xv

. xvi

. xiv

. iv

. xv

. v

. vii

. vi

. iv

. xv

. xv

. viii

Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 188 AUGUST, 1919 No. 2

ELECTRICAL TREATMENT OF SEWAGE: THE LANDRETH DIRECT OXIDATION PROCESS.*†

BY

HENRY JERMAIN MAUDE CREIGHTON,
Department of Chemistry, Swarthmore College,
and
BENJAMIN FRANKLIN,
Civil Engineer.
Members of the Institute.

I. INTRODUCTION.

THE first mention of the use of electricity in the purification of sewage is contained in an English patent, No. 1499, issued to J. Chisholm in 1856, for a process of disinfecting and deodorizing by electric or galvanic agency noxious or infected matters, such as occur in cesspools or sewers. No successful application seems to have been made of this process or of a number of other similar processes patented between the years 1870 and 1886.

Among the best known of the electrical processes is that invented by Webster, and installed experimentally at Crossness, England, in 1889, to treat London sewage. In this process the raw sewage flowed, in contact with iron electrodes, through long

* Communicated by the Author.

† This paper embodies the results of an investigation of the Landreth Direct Oxidation Process by the Committee of Science and the Arts of The Franklin Institute.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

COPYRIGHT, 1919, by THE FRANKLIN INSTITUTE.

troughs, each section of which was made of two, four or more longitudinal parts bolted together but insulated from each other. In the electrolysis cell a current density of 0.9 ampère maintained by an electromotive force of about 2 volts was employed. For the treatment of raw sewage it was estimated that 240 pounds of iron and 450 kilowatt hours of electrical energy would be consumed per million gallons. In this process most of the nascent oxygen liberated at the anode was consumed in oxidizing the iron of the electrode, and the oxide thus formed acted as a precipitating agent on the sludge of the sewage. The process, therefore, was mainly one of chemical precipitation by means of the oxide of iron formed by the action of the electric current.

Plants operating along the general lines of the Webster process are in use in Santa Monica, California, and in Oklahoma City, Oklahoma. While no careful studies have been reported from either of these plants, it is understood that, for a time at least, both gave satisfactory results so far as purification was concerned.

To a second type of so-called electrical process for the purification of sewage belong those in which nascent chlorine, liberated by the electrolysis of a chloride, acts as a disinfectant. A process of this kind was first developed by E. Hermite, in 1887. The sewage was mixed with chlorides of magnesium, calcium or sodium, and the liquid thus charged was passed in thin sheets or streams between electrodes. In a similar process invented by A. E. Wolff, a strong brine solution was electrolyzed, and the resulting chlorine and caustic soda were allowed to recombine in the form of sodium hypochlorite, the solution of this latter substance being used for purifying the sewage. In 1893, the sewage of about thirty dwellings at Brewster, N. Y., was treated by the addition of hypochlorite solution made in this way, under the direction of the Health Department of New York City.[1] For every million gallons of sewage treated, 1600 pounds of salt were used, and the plant required an electric current of 700 ampères at 5 volts. "This seems to have been the first plant established for the specific purpose of destroying bacteria. Before that time the removal of organic matter had been the aim."[2]

Extensive investigation has shown that electrical treatment of sewage is capable of practical use, but that the precipitants and disinfectants prepared by electrolysis will have the same efficiency

[1] *Eng. News*, 30, 41 (1893).

[2] *Water Supply Paper* No. 229, p. 27, U. S. Geol. Survey.

and no greater efficiency as when manufactured outside. As Kennicut, Winslow and Pratt point out,[3] "the important question is whether electrolysis in the presence of the sewage is or is not the most economical method of preparing and applying such precipitants and disinfectants as are needed. If the problem is regarded from this practical standpoint and without vague mystical conceptions of the purifying agency of electrical energy as such (which are apt to cloud the matter in the lay mind), a sound conclusion may be reached in any given case by a careful consideration of operating costs; and this conclusion will not generally be in favor of electric treatment."

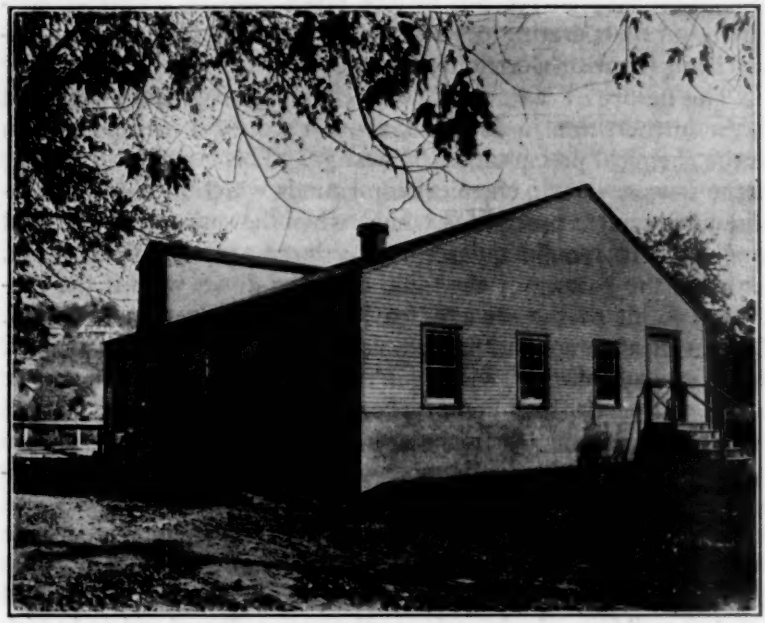
The failure of sedimentation to clarify sewage thoroughly led to the introduction in England, about 1860, of a method known as the chemical precipitation of sewage. This consists in adding to the sewage certain chemical compounds which produce a voluminous flocculent precipitate which, when the sewage thus treated is allowed to remain quiescent in a large tank for some time, settles to the bottom of the tank, carrying down with it the suspended solids of the sewage, leaving a clear supernatant liquid. The chemical compound first employed for this purpose was lime, which was added to the sewage in the form of milk of lime. The action of lime depends upon its combining with the carbonic acid and soluble carbonates in the sewage to form insoluble calcium carbonate, which in settling out carries down with it the suspended solids. The quantity of lime which it is necessary to employ depends upon the character of the sewage, an acid sewage requiring more than one which is neutral or alkaline. If too little lime is added to the sewage, sedimentation takes place slowly and it is impossible to obtain a clear effluent; on the other hand, with the addition of too much lime, varying quantities of the suspended organic matter in the sewage are rendered soluble, thus causing the effluent to be more putrescent and obnoxious than that from ordinary sedimentation.

In the Landreth Direct Oxidation Process for the treatment of sewage, both electricity and lime are employed. The efficacy of the process, as will be seen later, depends upon the combination of these agents, neither electricity nor lime alone producing such good results. The electric current liberates at the electrodes oxygen and hydrogen which in the nascent state are claimed to

[3] Kennicut, L. P., Winslow, C. E. A., and Pratt, R. W.: "Sewage Disposal," 1919. John Wiley & Sons, New York.

promote the destruction of pathogenic bacteria, and a reduction of the nitrogenous organic matter to albuminoids, peptones and amino compounds, which are subsequently oxidized to nitrites, nitrates and carbon dioxide. The presence of lime furnishes not only an alkaline medium which lowers the electrical resistance of the sewage and renders the electrodes passive, thus very greatly

FIG. 1.

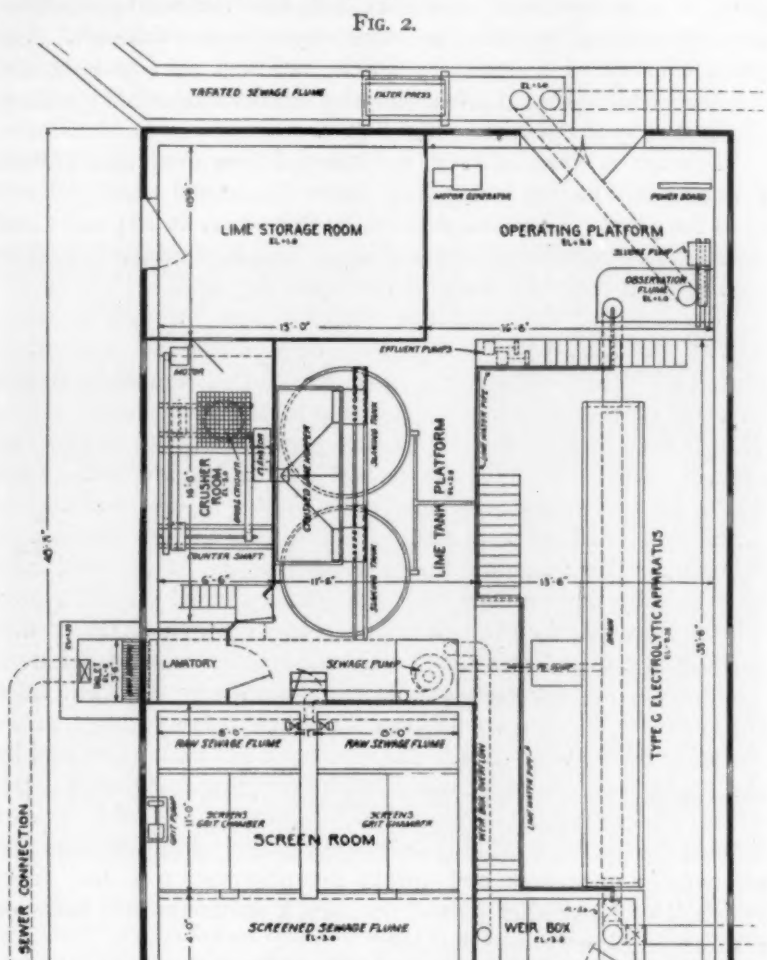


decreasing the quantity of iron which passes into solution from the anode, but it also aids in sedimentation. The process differs from others that employ electricity, in that purification is effected neither by the action of dissolved iron as a coagulant, nor primarily by the disinfecting action of nascent chlorine produced by electrolysis.

The Landreth process has been extensively studied at the 750,000 gallon unit installed at Elmhurst, Long Island, in 1915, by Messrs. Mason, Olsen and Mailloux, and by the Bureau of Sewer Plan of New York City; and later at Decatur, Illinois. Since then the process has been somewhat altered, and in the Spring of 1918 a plant with a million gallon unit embodying the

inventor's improvements was erected at Easton, Penna., by Mr. Landreth for demonstration purposes.

FIG. 2.



II. DESCRIPTION OF PROCESS AND PLANT.

The plant at Easton occupies a corner site, at Front and Spring Garden Streets, adjoining one of the city recreation parks, and is only two squares distant from the business centre of the city.

Its location in the heart of the residential district and the entire absence of complaints and unfavorable comments indicate that the plant is not considered a nuisance, and that the nearby residents are not annoyed by odors or other objectionable features. The plant consists of a one-story frame building, 48 feet long and 33 feet wide (Fig. 1), the interior construction of which is illustrated by the plan shown in Fig. 2.

Sewage is obtained from the Front Street sewer, an 18-inch concrete dam having been placed below the lateral which delivers it to the plant. The area drained by this sewer is 104 acres and includes two hotels and one brewery. The approximate estimate of the population tributary to the sewer is 7000.

On entering the plant the sewage passes through a coarse screen 3′6″ x 4′, framed with bars 0.25″ thick and 1.5″ deep, placed 1.5″ apart from centre to centre, and is elevated by means of a 6″ submerged centrifugal pump to the raw sewage flume, from where it flows throughout the plant by gravity. The raw sewage flume distributes the sewage over a flat inclined screen, 6′6″ x 8′, having six 0.25″ perforated holes to the square inch. These perforations are made so that the smooth surface is upwards. The material caught by this screen is removed continuously by five brushes 60″ in length arranged on a traveler. The sewage passes through this screen to a grit chamber and then on to a 3-foot measuring weir, the crest of which is of steel. The gauge for measuring the flow is placed four feet back from the crest of the weir, the zero of the gauge corresponding to the elevation of the weir crest. The discharge has been calculated by the Bazin formula which gave results proportional to the depth of the discharge over the weir. After being mixed with milk of lime at the spillway of the weir, the sewage passes through the electrolytic apparatus and enters the observation flume, from which it can be either passed through a sedimentation basin or discharged directly into the river.

The solid material obtained from the bar-screen which protects the centrifugal pump consists largely of paper and labels from the bottling house of a nearby brewery and amounts on an average to about 20 pounds per million gallons. Above the grit chamber the flat screen collects from two to three pails, each of three gallons, per 24 hours. The greatest part of these screenings consists of grain and hops from the brewery and vegetables from the hotel kitchens, very little fæcal matter being found.

The electrolytic apparatus (Fig. 3 and Fig. 3a) consists of a horizontal cypress box, 27′3″ long, 3′ wide and 2′9″ deep, mounted on supports 18″ above the floor. The top of the apparatus, which is removable, is made in two sections bolted to the sides and made water-tight with a rubber gasket. Vents are provided in each section of the top for the gaseous products of electrolysis, and a series of valves in the bottom of the tank serve to remove any sediment that may be deposited.

FIG. 3.

Internally, the tank is divided into eleven spaces, each of which contains two banks of electrodes (Fig. 4.) mounted one above the other, giving a total of twenty-two banks of electrodes arranged in two horizontal rows of eleven each. These banks of electrodes, each of which consists of 48 mild steel plates, 10″ x 16″ x 3/16″, spaced ⅜″ apart, are placed across the tank, the plates being vertical and parallel to the sides. The 48 plates of each bank are electrically connected so that alternate plates have the same polarity. The spaces between the banks and the sides of the tank are blocked up, compelling the sewage to flow between the

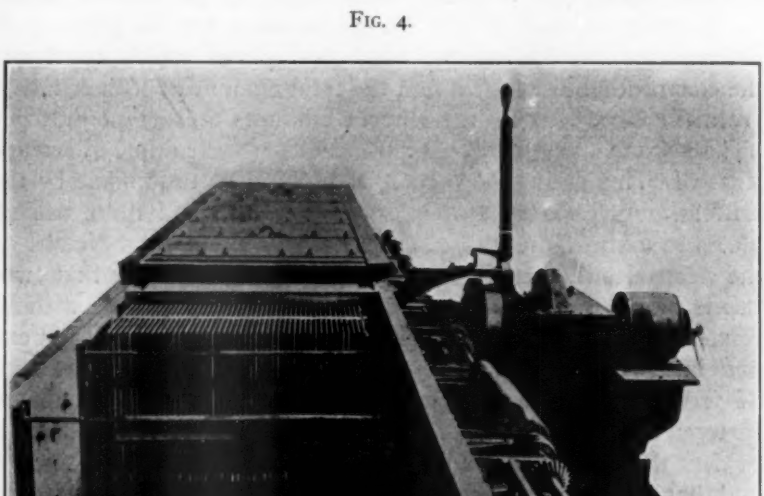
3/8" spaces between the electrodes. There are no partitions or baffle plates, the sewage flowing straight through the tank from one end to the other. The electric current passes through the twenty-two cells in series, but as these are all in the same body of liquid there is necessarily some leakage of current from one set of electrodes to another through the liquid, and the electricity which leaks in this way performs electrolysis less than twenty-two times.

FIG. 3a.

In each of the 3/8" spaces between the electrodes, two paddles or agitators are revolved, being attached to shafts passing through holes punched in the electrodes to receive them. These paddles are placed between the electrodes when the banks are assembled, their hubs being so shaped and interlocked that they remain in position to receive the shaft and insulate it from the electrodes. An electric motor drives the paddles at a speed of 20 R.P.M., the power being transmitted through the double reduction gear box and the two banks of protected bevel gears shown in Fig. 3a and Fig. 4. The two shafts for revolving the paddles are, for each two

banks of electrodes, electrically connected by means of braces in the outside mechanism for driving them; each pair is insulated from the next by a leather coupling. The voltage between two neighboring pairs of shafts is about 6, or about equal to that of two cells. This necessarily gives rise to internal cross-currents which reduce the electrolytic action, but this reduction is probably not large. A more serious result is that those shafts which act as anodes to this leakage current will become corroded electrolyti-

FIG. 4.



cally. This could be avoided entirely by omitting the connecting braces, thereby insulating each shaft from all of the others, leaving only the leakage current which may enter the same shaft, which is presumably very small, if indeed it exists at all.

As each electrode has an unobstructed area of 120.2 square inches per side, and as the 48 plates of each bank of electrodes are electrically connected so that alternate plates have the same polarity, each bank contains 5649.4 square inches of positive and negative electrode area respectively. The total positive and negative electrode area in the electrolytic apparatus, which contains 22 banks of electrodes, is, therefore, 124,286.6 square inches, respectively. The total number of paddles is 2068.

With the arrangement just described, the sewage is brought into intimate contact with the electrodes, thus enabling the nascent oxygen and hydrogen to be used effectively. In its course through the tank the sewage flows for 14 feet 8 inches between electrodes, and for 11 feet 10 inches through the spaces at the ends, in the middle and through the spaces between the banks of electrodes, which latter spaces are 7 inches. Hence during about 55 per cent. of the time or distance of flow through the tank, the sewage is under electrolytic treatment, and during 45 per cent. it is not.

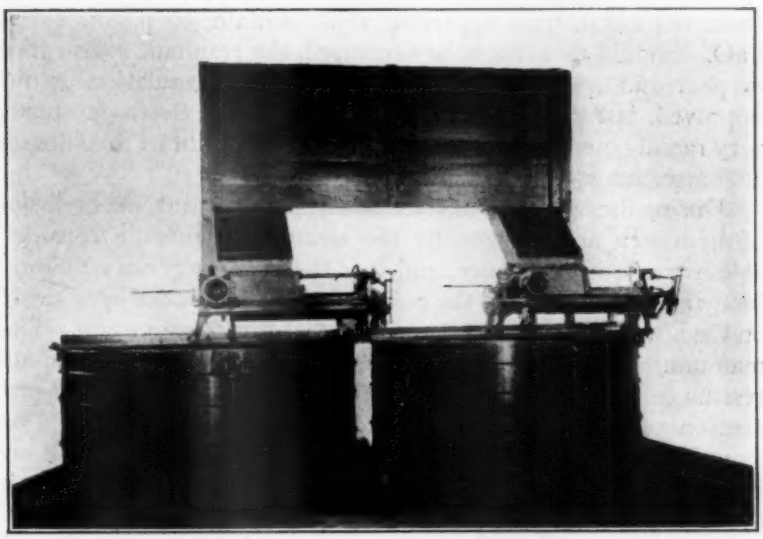
Experiments carried out by the inventor for the purpose of determining the life of the mild steel plates which constitute the electrodes, have shown that the total amount of iron removed from the electrodes by the current amounts to 1.41 pounds per 24 hours, and is not in any way influenced by the volume of sewage treated. This figure has been substantiated by tests made by the writers. As each plate weighs 8.33 pounds, and there are 48 plates in each of the 22 banks of electrodes, the total weight of the electrodes is, therefore, 8796.5 pounds. Assuming that two-thirds of the metal can be removed from the electrodes without rendering them useless, it follows that 5864.3 pounds of iron can pass into solution without destroying the electrodes. On account of frequent reversal of polarity, the loss of iron is distributed between all the electrodes. From the figures just given, it is evident that the life of the electrodes should be about 11.4 years, and that the electrolytic corrosion of the iron is a negligible factor. The electrodes of the tank at Easton were examined by the writers, after having been in use for many months, and showed no visual signs of wear, the edges being still sharp.

At this plant provisions are made for using either lump or hydrated lime. When lump lime is used the lumps are broken up on a 3-inch grid placed over the crusher, which reduces it to the size of cracked corn and discharges it into the boot of an elevator. A spout is provided so that hydrated lime may enter the elevator directly. The crushed or hydrated lime is elevated to a divided overhead hopper mounted above the two slaking tanks (Fig. 5), each of which is 7 feet in diameter and 3 feet high, only one of which is used at a time. The lime is discharged from the overhead hopper into either of these slaking tanks at their sides by adjustable feeding devices which are mounted on trusses supported by the sides of the tanks, and are actuated by the same motor that drives the agitator in the bottom of the tank.

Either city water or, as is generally the case, the effluent from the process is used for slaking the lime. The effluent is pumped into the bottom of either of the tanks by a one-inch centrifugal pump connecting with the observation flume and the milk of lime is discharged from the top of the tanks through suitable piping into the spillway of the weir or into the outlet pipe of the electrolytic apparatus.

The construction of the feeding device is very simple, consisting of a reciprocating link driven by an eccentric, which by

FIG. 5.



means of pawls and a ratchet actuates the feed worm. The quantity of lime discharged into the slaking tanks depends upon the number of revolutions of the feed worm and this may be controlled by changing the position of the eccentric or by varying the number of teeth engaged on the ratchet by changing the position of the pawl arm, permitting a total of 87 adjustments.

It has been mentioned previously that one of the functions of the lime is to render the electrodes passive, so that they will not be corroded by electrolytic action. After the electrodes have become passive, the crystalloids of calcium carbonate produced by the action of the lime on the sewage begin to accumulate on them. This increases the power required to rotate the paddles, which

is indicated by a watt-meter placed in the circuit of the motor that drives them. When this motor indicates 2000 watts, the addition of lime to the spillway of the weir is discontinued and it is then admitted to the outlet pipe of the electrolytic tank. Under these conditions the acid content of the sewage dissolves the crystalloid deposit without affecting the production of nascent hydrogen and oxygen. As soon as the watt-meter reading becomes normal (1000–1200 watts), the lime is again admitted to the spillway of the weir and its addition to the outlet pipe of the electrolytic apparatus discontinued.

The normal operation of this process requires that the effluent from the electrolytic apparatus shall contain 30 p.p.m. excess CaO. Should this excess be decreased, the resultant coagulation is poor, and when greatly increased the coagulation is not improved, but the crystalloid deposit upon the electrodes forms very rapidly, necessitating the reversal of the point of lime dosage at shorter intervals.

During the operation of the electrolytic apparatus, the occlusion of hydrogen and oxygen by the electrodes causes a considerable increase in resistance, and it is therefore necessary at four-hour intervals to change the polarity of the electrodes by a switch on the powerboard in order to counteract this phenomenon. This maintains the electrodes in a passive condition and keeps the resistance of the apparatus practically constant, while the production of nascent hydrogen and oxygen is unimpaired. An increase in resistance is also occasioned by electrolytic depositions on the electrodes taking place. This is indicated by a rise in the voltage of the electrolytic apparatus and a fall in the current strength. When, therefore, the voltage and the current strength attain certain values, the direction of the current is reversed and then these deposits re-dissolve.

The method of operation that has been adopted at Easton to take care of the wide variations in both the flow and the character of the sewage is exceedingly simple and ensures satisfactory results at all times, but it is much more expensive than would be the case were the sewage flow equalized, as more lime is required continuously to take care of the variations of the sewage.

The total consumption of energy *chargeable directly to the process* is that used for electrolysis, that for driving the paddles, that for pumping a portion of the effluent into the lime-mixing tank, and that for driving the stirrer and feeder of this tank.

All this energy, and none other, is measured in a sealed General Electric Company's kilowatt-hour meter attached directly to a three-phase, 60-cycle, 220-volt alternating current. Part of the current which passes through this meter operates a motor generator, which furnishes the direct current for electrolysis. That portion of the total power which as direct current passes through the electrolytic tank, is read separately on a voltmeter and ammeter; that portion which is used for driving the paddles located between the electrodes is measured on a separate indicating wattmeter.

The voltage of the individual cells ranges from 2.5 to 3.7 volts, averaging about 2.82 volts, while a current of 34 ampères is flowing.

III. EXPERIMENTAL RESULTS.

In order to determine the efficacy of the Landreth Direct Oxidation Process, an investigation was carried out at the demonstration plant at Easton, on February 18th, 19th, 20th and 21st, during which time the plant was operated under the direction and constant supervision of one of the writers and his two assistants, Messrs. O. R. Quayle and J. D. Ballard. Composite samples of both the raw sewage and the effluent were prepared from half-hour samples of these liquids, and the chlorine, nitrite, nitrate, required oxygen and dissolved oxygen were determined in the former samples immediately after obtaining them. Portions of these composite samples were sent at once to Mr. James DeLong, at Lafayette College, Easton, Pa., who made determinations of albuminoid and free ammonia. The bacteria content was determined by Dr. E. Q. St. John, of Philadelphia, in samples of both the raw sewage and the effluent taken every two and one-half hours, or oftener, during the runs. The bacteria samples were kept on ice and sent to Philadelphia daily by special messenger.

One litre of each composite sample of raw sewage and of effluent was placed in bottles of that volume, with only a small air space at the top to allow for expansion, and sent to the Chemical Laboratories of Swarthmore College, where the dissolved oxygen remaining in the samples at the end of five days and the suspended matter were determined.

Owing to the fact that the composition of the raw sewage delivered to the plant was liable to vary greatly from moment to moment, it was necessary, in order that the influence of the elec-

trolytic-lime treatment might be ascertained, to determine the time required for the sewage to pass from the point where the samples of raw sewage were collected, to that point where the samples of effluent were taken. This was accomplished by adding a suitable dye to the sewage at the first point and noting the time required for the color to appear at the second point. From the spillway of the weir, and from the entrance to the grit chamber, points at which samples of raw sewage were collected, 95 seconds, and 3 minutes, respectively, were required by the sewage to pass to the observation flume where the samples of effluent were taken. Therefore, by allowing this time to elapse between taking the samples of raw sewage and effluent, there were obtained corresponding samples. It might be of interest to mention that several of the dyes employed, as well as phenolphthalein, were decolorized while passing through the electrolytic apparatus. The individual samples of both raw sewage and effluent, of which the respective composite samples were composed, were made by dipping up three portions of 250 c.c., thirty seconds elasping between each dip.

During the tests covered by analyses 1 to 9 inclusive, the hydrated lime was fed into the mixing vat at the rate of 856.4 pounds per 24 hours, or an equivalent of 672 pounds 90 per cent. CaO lump lime. The milk of lime so formed was added to the raw sewage at the spillway of the weir at the rate of 30 gallons per minute. The lime was found on analysis to contain:

	Per cent.
CaO	71.36
$Fe_2O_3+Al_{23}$	2.47
Cl	0.5
CO_2	0.0

The purification process, *operated in the manner recommended by the inventor* (*i.e.*, the use of electricity and lime), was tested over a period of 35.5 hours, this period being made up of a run of 14.5 consecutive hours on February 18th, during which three composite samples for chemical analysis and six samples for bacteriological examination were taken; and a run of 10 and another of 3 consecutive hours on February 19, covered by three composite samples for chemical analysis and nine samples for bacteriological examination; and a run of 5 and another of 3 consecutive hours on February 19th, covered by two composite samples for chemical analysis and 6 samples for bacteriological examination. During these three days the weather was cold and fine.

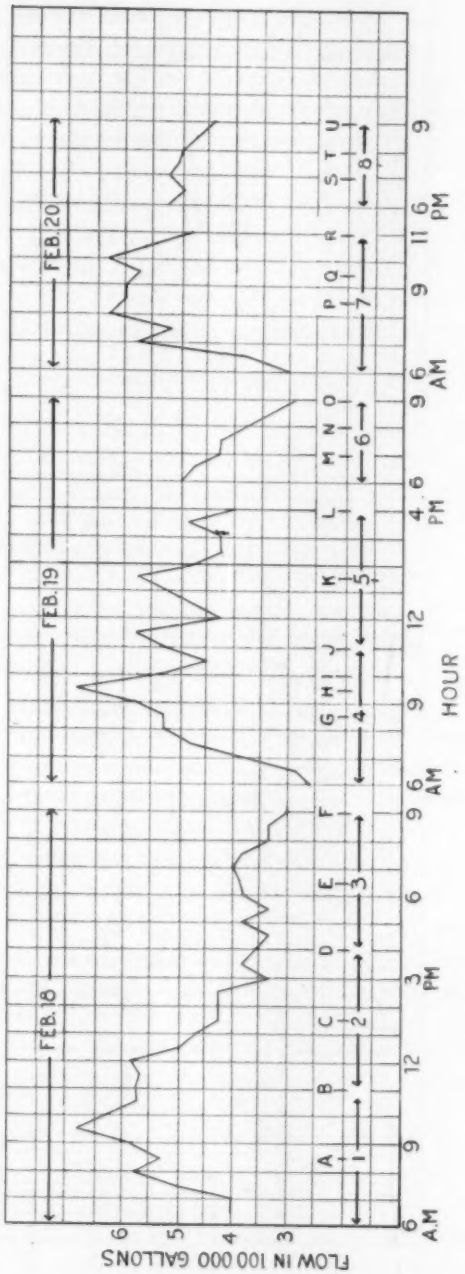

FEB. 18
FEB. 19
FEB. 20
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
1
2
3
4
5
6
7
8
6 A.M.
9
12
3 PM
6
9
12
9 AM
HOUR
3
4
5
6
FLOW IN 100 000 GALLONS
4 6 PM
9 6 AM
9 11 6 PM
9

FIG. 6.

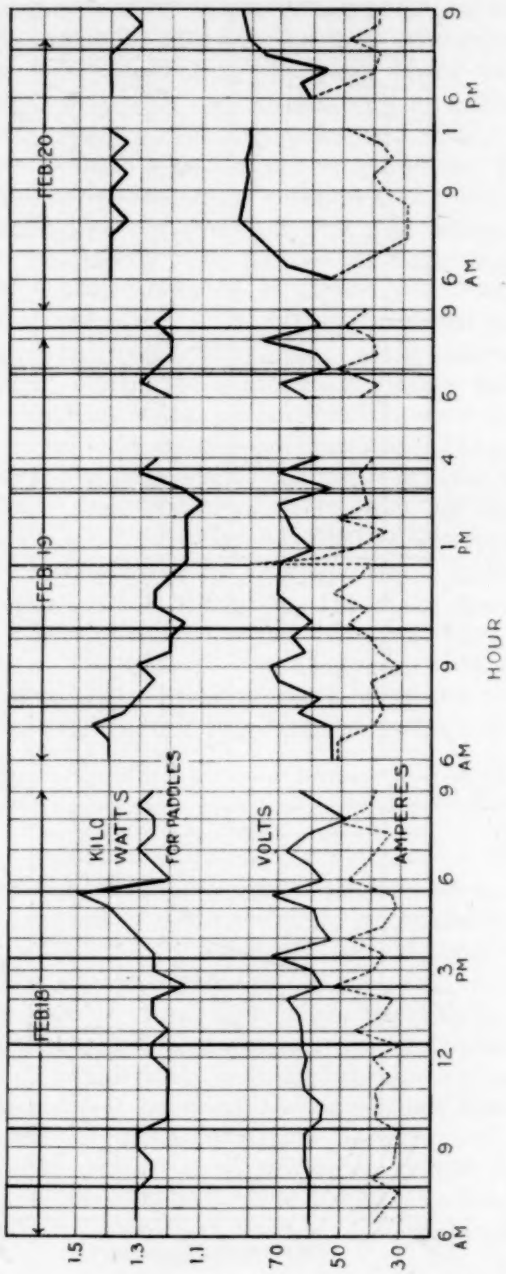

FEB 18
FEB 19
FEB 20
KILO WATTS
FOR PADDLES
VOLTS
AMPERES
HOUR
6 AM
9
12
3 PM
6
9
12
1 PM
4
6
9
12
3 PM
6
9
1.5
1.3
1.1
70
50
30

Fig. 7.

Variations in the flow of sewage during these periods are shown by the curves in Fig. 6. In this figure are indicated by the numerals, 1 to 8, the periods covered by the composite samples taken for chemical analysis, and by the letters, *a* to *u*, the times at which samples were taken for bacteriological examination.

In Fig. 7 are shown graphically the variations in the voltmeter, ammeter and wattmeter readings. The hours at which the direction of the current through the electrolysis tank was reversed are indicated by the heavy vertical lines. It will be seen that, for the most part, the current was reversed when the voltage was high and the ampèrage low. Further, it will be observed that the form of the voltage and ampèrage curves on February 20th is quite different from those for the two preceding days, a high voltage being necessary to maintain the normal operating current. On this day a considerable quantity of grease was observed in the effluent. It is believed that the presence of the grease considerably increased the electrical resistance of the sewage.

In Table I are given the analytical data and the average of the bacteriological data obtained for the periods indicated, for both the raw sewage and for the effluent.

As it had been suggested that the efficiency of the process was due primarily to the action of the lime which was thoroughly mixed with the sewage in the electrolytic apparatus, electricity playing but a minor part, the examination at Easton included an investigation of the efficacy of the apparatus in the purification of sewage, (1) when the raw sewage, after having been mixed with the usual quantity of lime suspension, was passed through the tank and subjected to thorough mixing by the paddles, without electricity; and (2) when the raw sewage to which no lime had been added was subjected to the action of the electric current in the tank. As the inventor was of the opinion that the electrode would be damaged by allowing the lime-containing sewage to flow through it in the absence of the electric current, or by operating it with electricity in the absence of lime, for periods longer than one hour, the tests just mentioned each extended over a period of sixty minutes. During these two periods composite samples were prepared by taking portions of both the raw sewage and the effluent at intervals of five minutes, while for bacteriological examination samples were taken every ten minutes during the

TABLE I.

Landreth Direct Oxidation Process.
Regular Practice: Electrolytic-Lime Treatment.
R = raw sewage. E = apparatus effluent.

No. of composite sample			1	2	3	4	5	6	7	8	Average	Change P. P. M.	Change Per cent.
	Chlorine, P. P. M.	R	55.5	65.6	64.6	60.5	70.3	64.5	56.5	58.1	61.9		
		E	63.0	77.6	65.2	44.6	60.3	61.8	64.8	67.9	63.1	+ 1.2	+ 1.9
Nitrogen as—	Nitrite, P. P. M.	R	0.009	0.025	0.030	0.035	0.025	0.019	0.033	0.028	0.024		
		E	0.028	0.043	0.036	0.050	0.030	0.028	0.023	0.040	0.038	+ 0.014	+58.3
	Nitrate, P. P. M.	R	0.62	0.52	0.50	0.46	0.75	0.67	0.50	0.41	0.55		
		E	0.77	0.64	0.60	0.50	0.63	0.85	0.83	0.63	0.68	+ 0.13	+23.6
	Free Ammonia, P. P. M.	R	17.2	.....	.....	17.0	.....	17.8	19.8	.....	18.0		
		E	15.6	.....	.....	13.9	.....	14.4	14.8	.....	14.7	− 3.3	−18.3
	Albuminoid NH_3 P. P. M.	R	27.9	.....	.....	32.2	.....	29.3	29.6	.....	29.8		
		E	26.3	.....	.....	28.1	.....	25.2	25.3	.....	26.2	− 3.6	−12.1
	Required oxygen P. P. M.	R	51.4	71.2	65.8	61.9	74.9	64.5	59.0	59.5	63.5		
		E	43.0	54.1	58.6	43.6	55.4	51.2	52.0	46.2	50.5	−13.0	−20.5
Dissolved Oxygen	Determined Immediately, P. P. M.	R	3.88	3.90	(6.55)	4.26	5.09	5.22	3.98	4.14	4.35		
		E	7.39	5.92	5.76	5.76	6.40	6.20	5.14	6.22	6.13	+ 1.78	+40.9
	Determined after 5 days (10–15), P. P. M.	R	0.21	0.19	0.26	0.15	0.22	0.28	0.09	0.05	0.18	Absorption of oxygen on standing: in P. P. M. R = 4.17, E = 0.77; in % R = 95.9, E = 12.6	
		E	6.70	5.64	5.57	4.11	6.14	5.75	4.06	4.98	5.36		

Suspended solids, P. P. M.		E	256	268	169	293	271	193	251	182	235		
Temperature, °C.		R	7.4	7.5	7.5	7.7	7.9	7.9	8.9	9.1	8.0		
		E	8.1	8.3	8.4	8.6	8.8	8.8	9.7	9.9	8.8		
Bacteria: Total count per c.c., at 37°		R	215000	155000	250000	312000	475000	425000	527000	603000	370000		
		E	28000	6000	27400	25000	37000	20300	32300	37300	26800	−343200	−92.7
Bacteria: Total count per c.c., at 20°		R	500000	455000	625000	530000	550000	757000	1017000	1533000	746000		
		E	82000	40000	42000	91000	62000	47000	47000	51000	58000	−688000	−92.2
Bacteria: B. coli per c.c.		R	100000	100000	55000	100000	55000	70000	100000	40000	78000		
		E	<10	<10	<10	250	<10	<10	670	0	120	−77880	−99.85
Period in hours			4.5	5	5	5	5	3	5	3			
No. half-hour samples in composite			9	10	10	10	10	6	10	6			
Average flow of sewage in 1000 gals. per 24 hrs.			543	446	358	468	481	388	532	496	464		
Power consumed, kw. hours			29	26	29	28	33	21	33	24		213 kw. h. for 686,000 gals.	
Kw. h. per hour			6.4	5.2	5.8	5.6	6.6	7.0	6.6	8.0	6.4		
Kw. h. per 1000 gals. sewage.			0.29	0.28	0.39	0.29	0.33	0.43	0.29	0.38	0.335		

hour. These tests were made on February 21st, on which day there was a light fall of snow which melted rapidly. The variations in the sewage flow during the two tests are shown graphically in Fig. 8, and the electrical data are shown in Fig. 9. The results of the chemical analyses and the bacteriological examination which cover the two tests are given in Table II.

FIG. 8.

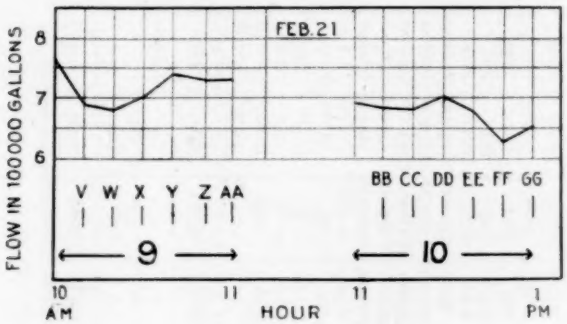
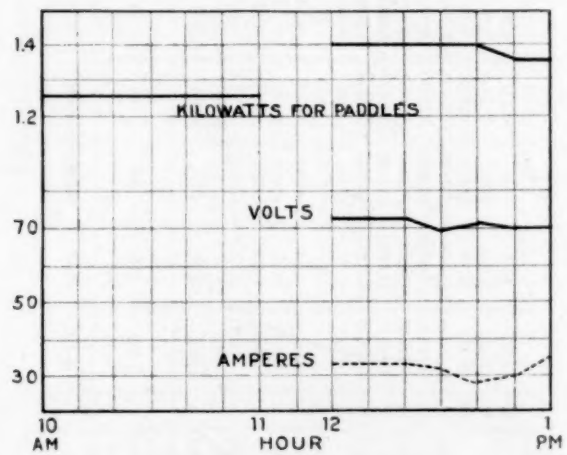


FIG. 9.



IV. DISCUSSION OF RESULTS.

Various standards for the purity of sewage effluents have been formulated from time to time. Kinnicutt, Winslow and Pratt state in their book just published that " in the United States the usual requirement is that the effluent must be non-putrescible, or must contain only that amount of organic matter which, when

TABLE II.

			Lime treatment. Only in the Landreth Apparatus. Composite sample No. 9			Electrical treatment. Only in the Landreth Apparatus. Composite Sample No. 10		
			P. P. M.	Change P. P. M.	Change per cent.	P. P. M.	Change P. P. M.	Change per cent.
	Chlorine	R	67.7			70.8		
		E	80.0	+12.3	+18.2	72.4	+1.6	+ 2.2
Nitrogen as	Nitrite	R	0.050			0.050		
		E	0.045	− 0.005	−10.0	0.040	−0.01	−20.0
	Nitrate	R	0.62			0.75		
		E	0.625	+ 0.005	+ 0.8	0.60	−0.15	−20.0
	Free NH_3	R	15.6			13.5		
		E	15.8	+ 0.2	+ 1.3	14.4	+0.9	+ 6.6
	Albuminoid NH_3	R	23.8			22.2		
		E	23.4	− 0.4	− 1.7	21.7	−0.5	− 2.3
	Required oxygen	R	84.6			64.5		
		E	76.9	− 7.7	− 8.9	58.0	−6.5	−10.0
Dissolved Oxygen	Determined immediately	R	4.88			4.01		
		E	3.95	− 0.93	−19.1	5.62	+1.61	+40.1
	Determined at end of 5 days	R	0.03	Absorption of oxygen on standing: in P. P. M. R = 4.85, E = 3.82; in % R = 99.4, E = 96.7		0.08	Absorption of oxygen on standing: in P. P. M. R = 3.93, E = 5.17; in % R = 98.0, E = 92.0	
		E	0.03			0.45		
Bacteria *	Total count per c.c., at 37° C.	R	1,180,000			437,000		
		E	453,000	.....	−82.4	272,000	.....	−37.8
	Total count per c.c., at 20° C.	R	1,192,000			908,000		
		E	118,000	.....	−90.1	273,000	.....	−70.0
	B. coli per c.c.	R	100,000			55,000		
		E	3,700	.....	−92.3	10,000	.....	−81.8

R = Raw sewage. E = Effluent.
* Bacteria values are the average of six samples taken every 10 minutes during an hour.

the effluent is emptied into a stream, can be oxidized by the oxygen contained in the water at the time of the minimum flow; and that it must be sufficiently freed from suspended solids to avoid the accumulation of sludge banks or the creation of surface conditions offensive to sight and smell. In certain cases, as when the effluent is emptied into a stream in the near neighborhood of a point at which water is taken for domestic use, or is emptied into salt water in the neighborhood of shellfish layings, the effluent must also be freed from the great majority of the sewage bacteria."

"The International Boundary Commission, as a result of its study of pollution in the Great Lakes, suggested that the raw water to be treated by a purification plant should contain not over 500 *B. coli* per 100 c.c. as an annual average, and should not show *B. coli* in more than half of a series of 0.1 c.c. samples if satisfactory results are to be secured. According to this standard it would naturally be required that sewage treatment should be carried far enough so that after dilution has taken place the effluent discharged shall not produce, at any neighboring water works intake, a raw water of greater bacterial impurity than that specified above. The requirement of the Commission is perhaps an unduly strict one since many filtration plants (such as that of Cincinnati) are treating waters much more polluted than this with success."

"Authorities in America generally consider that more valuable information can be obtained from the study of the nitrogen data than from any of the other factors, while in England and Germany greater importance is placed on the oxygen consumed. If total carbon could be determined easily, this determination would probably be most valuable. Oxygen consumed, however, does not bear a constant relation to total carbon and is open to the same objections as albuminoid nitrogen."

"The latest and most authoritative standard of this kind is the one formulated by the Royal Commission on Sewage Disposal in its Eighth Report (R.S.C., 1912). It provides as a general standard that a sewage effluent must not contain as discharged more than 30 parts per million of suspended matter and must not take up more than 30 parts per million of dissolved oxygen in 5 days at 18.3° C. If the volume of diluting water available is 150–300 times the volume of the effluent the dissolved oxygen

test may be omitted and 60 parts of suspended solids would be permissible; if the volume of diluting water is 300–500 times the volume of the effluent the limit of suspended solids may be raised to 150 parts; while if the diluting volume is 500 times that of the effluent all standards might be dispensed with provided necessary screens and detritus tanks were provided."

In Table III are compared the changes brought about in raw sewage by:

1. Electrolytic-lime treatment with the Landreth apparatus;
2. Lime alone with the Landreth apparatus;
3. Electricity alone with the Landreth apparatus.

TABLE III.

Change Produced in Sewage by the Landreth Apparatus Operated With:

		Lime and Electricity		Lime alone		Electricity alone	
		P. P. M.	Per cent.	P. P. M.	Per cent.	P. P. M	Per cent.
	Chlorine	+ 1.2	+ 1.9	+12.3	+18.2	+1.6	+ 2.2
	Nitrite	+ 0.014	+58.3	− 0.005	−10.0	−0.01	−20.0
	Nitrate	+ 0.13	+23.6	+ 0.005	+ 0.8	−0.15	−20.0
	Free ammonia	− 3.3	−18.3	+ 0.2	+ 1.3	+0.9	+ 6.6
	Album. NH_3	− 3.6	−12.1	− 0.4	− 1.7	−0.5	− 2.3
	Required oxygen	−13.0	−20.5	− 7.7	− 8.9	−6.5	−10.0
	Dissolved O_2	+ 1.78	+40.9	− 0.93	−19.1	+1.61	+40.1
	Dissolved . . . R = O_2 absorbed in 5 days . . . . . E =	4.17	95.9	4.85	99.4	3.93	98.0
		0.77	12.6	3.82	96.7	5.17	92.0
Bacteria Reduction	Total count at 37° C., per c. c.	−343,200	−92.7	− 373,000	−82.4	−165,000	−37.8
	Total count at 20° C., per c. c.	−688,000	−92.2	−1,074,000	−90.1	−635,000	−70.0
	B. coli at 37° C., per c. c.	− 77,880	−99.85	− 96,300	−92.3	−45,000	−81.8

From a comparison of the results recorded in Table III, it will be observed that with electrolytic-lime treatment the quantities of nitrite and nitrate in the sewage are increased, while with lime alone and with electricity alone a material decrease or but a slight increase is effected. With the electrolytic-lime treatment there is a marked decrease in free ammonia and albuminoid ammonia, whereas with the lime or with the electrical treatment

there is a small decrease in albuminoid ammonia, and an increase in free ammonia. The required oxygen is decreased by all three treatments, but that effected by the electrolytic-lime treatment is approximately double that brought about by either of the other methods. Due to the production of oxygen by the electric current, an increase in dissolved oxygen of about 40 per cent. is effected by the electrolytic-lime treatment and by the purely electrical treatment; while with lime alone a decrease of 19 per cent. in dissolved oxygen occurs.

The amount of the dissolved oxygen absorbed by the effluent in five days at a temperature of 10° C. to 15° C., affords very important information regarding the efficiency of the three methods of treatment. Indeed this test is regarded by many authorities as one of the most important standards for determining the purity of an effluent. The results recorded in Table III show that while practically all of the dissolved oxygen in the raw sewage is absorbed during the five-day period, that in the effluent produced by the electrolytic-lime treatment is reduced only 0.77 part per million, or 12.6 per cent., a figure which lies far below the limit allowed by the Royal Sewage Commission. On the other hand, nearly all of the dissolved oxygen in the effluents produced by the lime treatment and by the electrical treatment is absorbed in the five-day period, showing that by these methods the unstable organic matter in the sewage was but partially oxidized.

It will be observed that electrolytic-lime treatment brings about a reduction of over 92 per cent. in the total bacteria count, while the lime treatment effects a reduction of 82 per cent. at 37° C. and 90 per cent. at 20° C., and the electrical treatment produces a reduction of only 38 per cent. at the higher temperature and 70 per cent. at the lower temperature. The reduction in *B. coli* per c.c. amounts to 99.85 per cent. with the electrolytic-lime treatment, and to 92.3 per cent. and 81.8 per cent., respectively, with the lime treatment and with the electrical treatment.

It may be of interest to mention that the effluents produced by the different treatments were examined after having been kept in stoppered bottles for five weeks. Those obtained in runs 1 to 8 (electrolytic-lime treatment) had little or no odor; that obtained in run 9 (lime treatment only) had a very disagreeable odor, while that obtained in run 10 (electrical treatment only) smelled strongly of hydrogen sulphide, and had turned black

owing to the conversion of the iron dissolved from the electrodes into iron sulphide.

It is evident from the data recorded in Table III that not only is an highly satisfactory effluent produced by the Direct Oxidation Process, but that the combination of lime and electricity, when employed in the apparatus described, is much more effective in purifying sewage than either lime alone or electricity alone when employed with the same apparatus.

In judging the efficacy of the Direct Oxidation Process, it must be remembered that the data given in the preceding tables refer to the effluent as it comes from the electrolytic tank, and that by the conjunctive use of a sedimentation basin the suspended solids, consisting largely of lime, could be considerably reduced. This reduction would also be attended by a further decrease in albuminoid ammonia, required oxygen and the bacteria.

In order that the results obtained with the Direct Oxidation Process of sewage treatment may be compared with those obtained with other methods, analytical and bacteriological data relating to a number of methods are given in Tables IV and V.

V. COSTS AND COMPARISONS.

After a careful study of 16 different plants for sewage treatment in this country, varying in cost from $40,000 to $9,000,000, we still find it extremely difficult to make a comparison in cost either of construction or of operation of the electrolytic process of sewage treatment with other methods, since the conditions affecting the installation of a sewage treatment system vary greatly and frequently involve factors which in the aggregate are more costly than the construction of the plant.

Take, for instance, the selection of a site for a treatment plant. It must be sufficiently remote to avoid offense; its elevation should be low enough to receive the sewage by gravity or at least to minimize the cost of pumping; and it ought also to be reasonably close to a stream furnishing a proper outlet for the effluent. To meet these general conditions, heavy costs may be incurred in the purchase of land suitable for the purpose and frequently tracts thus acquired must be largely in excess of the actual needs of the plant so as to avoid the depreciation of adjacent land values. The cost also may be increased by the construction of long and expensive trunk line sewers; the construction of collecting basins and pumping stations for the purpose of lifting

TABLE IV.

Effect of Various Processes for the Treatment of Sewage.

Process	Location	Nitrogen as—					Required oxygen	Authority
		Suspended solids	Albuminoid NH_4	Free NH_3	Nitrates	Nitrites		
		in parts per million						
Chemical pptn. $CaO+FeSO_4$:	London, 1894							Dibdin, 1903.
Sewage		441	4.9	34.8	...	...	53.1	
Effluent		87	3.9	28.9	...	...	44.5	
Coke strainer:	Lawrence, Mass., average 4 years (1894–1898)							Winslow and Phelps, 1906.
Sewage		...	6.4	30.8	...	...	38.8	
Effluent		...	3.3	31.8	...	...	22.2	
Septic tank:	Lawrence, Mass., average 5 years (1898–1903)							Winslow and Phelps, 1906.
Sewage		232	7	38.1	...	...	49.5	
Effluent		107	3.3	37.7	...	...	27.3	
Sedimentation:	Birmingham, England							
Sewage		686	14.2	39.3	7	...	66	Watson, 1903.
Effluent		346	10.9	37.7	7.3	...	.....	
Broad irrigation:	South Norwood, England							Royal Sewage Commission, 1904.
Sewage		219	6.7	35.4	...	...	77.1	
Effluent		...	1	8.7	3.9	...	14.4	
Contact beds:	Mansfield, Ohio, 1907.							Kimberly.
Sewage		74	7.8	....	0.4	0.2	37	
Effluent		40	3.6	....	2.6	0.04	9.2	
Intermittent filtration:	Worcester, Mass., 1904							Kinnicutt, Winslow and Pratt.
Sewage		...	8.1	18	0.6	0.1	138.7	
Effluent		...	0.9	10.9	2	0.3	18.1	
Trickling filters:	Worcester, Mass., 1913							Kinnicutt, Winslow and Pratt.
Sewage		144	6.7	24.3	0.7	...	119	
Effluent		43	2.3	17.8	6	...	29	

the sewage across divides from one drainage area into another, so that treatment can be obtained at a central plant; and the property damages which in some cities result from the widening of streets and the changes of grades made necessary to accommodate concentrated drainage.

TABLE V.

Bacteria Reduction by Various Methods for Treating Sewage.

Intermittent Filtration at Brockton, Mass.

Kinnicutt, Winslow and Pratt.

	Total count per c.c. at 20	*B. coli per* c.c.
Raw sewage	3,150,000	150,000
Effluent A	1,900	400
Effluent B	6,300	15
Effluent D	125	0
Effluent E	1,400	5
Effluent F	2,000	1

Results of Experiments at Lawrence, Mass.

Metcalf and Eddy.

		Per cent. bacteria removed
Regular sewage, as received from force main at station	2,095,600	
Settled sewage	1,386,300	33.80
Effluent, strainer E (12″ depth buckwheat coal, rate 800,000 gals. per acre per day)	874,200	58.50
Fresh sewage (from toilet room at station)	3,241,600	
Effluent, Imhoff tank	1,700,300	46.60
Effluent, sand filters	2,565	99.88
Effluent, contact filters	1,105,600	47.20
Effluent, trickling filters	254,500	81.70

While it is true that in the electrolytic process described in this paper, a number of units are eliminated which are required in ordinary treatment systems, yet in a small electrolytic plant this saving is more than offset by the cost of the protective building which is necessary. In addition there is the constant employment of skilled labor which such a plant requires. Where it is possible to combine a water pumping station, an electric lighting plant, and a Landreth Direct Oxidation sewage treatment plant under one roof, the proportional cost of the protective structure, as well as operation, is reduced, making it a probable advantage to employ this method. When this cannot be done, the Landreth Direct Oxidation process is not in our judgment economical if the population tributary to the plant is very small.

Our experience at the Landreth Direct Oxidation plant in

Easton fully justifies the statement that a plant of this type can be installed and operated in any densely populated section without detection by the public.

The importance of this advantage is evident when it is considered that an inexpensive property of a few thousand square feet conveniently situated near outlets of main sewers is all that is required for this electrolytic process compared with the large areas at a distant point demanded by ordinary methods of sewage disposal.

TABLE VI.

Comparison of Cost of Operation Between 2,000,000 Gallon Plant and 10,000,000 Gallon Plant.

Capacity	2,000,000 gallons per day.
Population	20,000.
The operation cost is based upon the following daily items:	
1600 lbs. 90 per cent. lime per day at $6 per ton	$5.33
Current, 282 k.w. hrs. per day at 2 cents	5.64
Heat and light per day	2.00
Renewals	2.00
Maintenance and repairs	1.00
Labor:	
3 men—8 hr. shifts, at $5, $4, $4.	
1 laborer at $3	16.00
Total	$31.97
This is 58 cents per capita per year for operation, of which about 51 per cent. is for labor alone.	
Capacity	10,000,000 gallons per day.
Population	100,000.
The operation cost is based upon the following daily items:	
8000 lbs. 90 per cent. lime per day at $6 per ton	$26.75
Current, 1410 k.w. hrs. per day at 2 cents	28.00
Heat and light per day (estimated)	2.00
Renewals	10.00
Maintenance and repairs	6.00
Labor:	
1 superintendent	5.00
3 operators at $4	12.00
1 laborer	3.00
	$92.75
This is 34 cents per capita per year for operation, of which about 22 per cent. is for labor.	

TABLE VII.

Cost of Operation, Allowing Interest at 4 per cent. and 2½ per cent. Depreciation.

Location	Cost of plant	Population	Int. and dep. per cap.	Cost of oper. per cap.	Total cost per cap.	Authority	Remarks
Chicago	$9,258,600.00	1,600,000	$.38	$.27	$.65	Hering & Fuller	Includes intercepting sewer and pumping station.
N. Dist. Boston, Mass.	7,126,000.00	601,810	.77	.29	1.06	H. P. Eddy	Water dilution.
S. Dist. Boston, Mass.	8,944,000.00	438,580	1.33	.25	1.58	H. P. Eddy	Water dilution.
Worcester, Mass.	1,966,000.00	162,697	.79	.37	1.16	H. P. Eddy	Chemical precipitation and sand filters.
Fitchburg, Mass.	815,000.00	39,655	1.34	.26	1.60	H. P. Eddy	Imhoff and trickling filters.
Gloversville, N. Y.	378,000.00	21,178	1.16	.27	1.43	H. P. Eddy	Sedimentation and trickling filters.
Clinton, Mass.	149,000.00	13,192	.73	.57	1.30	H. P. Eddy	Sand filters, and pumping station.
Lebanon, Pa.	80,000.00	15,000*	.34	.65	.99	P. A. Volcknor	Imhoff and trickling filters.
York, Pa.	194,500.00	30,000	.42	.11	.53	J. K. Geisey	Imhoff and pumping station.
West Chester, Pa.	162,000.00	12,000	.88	.30	1.18	N. R. Rambo	Pumping plant and septic tank.
Indiana, Pa.	40,000.00	8,000	.32	.10	.42	Metcalf & Eddy	Septic tanks and trickling filter.
Typical plant†	431,710.00	55,000	.51	.31	.82	H. P. Eddy	Imhoff and trickling filter.
Typical plant†	313,880.00	55,000	.37	.73	1.10	H. P. Eddy	Activated sludge.
Electrolytic plant†	219,050.00	55,000	.26	.38	.64	Landreth	Electrolytic.

* Refers to population served by plant.
† No main sewer lines included in estimates of costs.

TABLE VIII.

Cost of Construction.

Location	Cost	Population for which plant was designed	Cost per cap. at time of use	Authority	Year of establishment	Remarks
Chicago, Ill.	$9,258,600.00	1,600,000*	$5.78	Hering & Fuller	1907	Includes trunk line sewers and trickling beds.
N. Dist., Boston, Mass.	7,126,000.00	571,000	12.48	H. P. Eddy	1916	Dilution in harbor.
S. Dist., Boston, Mass.	8,944,000.00	986,000	9.07	H. P. Eddy	1916	Dilution in harbor.
Worcester, Mass.	1,966,000.00	.....	9.31	H. P. Eddy	1916	Chemical precipitation and sand filters.
Fitchburg, Mass.	815,000.00	.....	12.88	H. P. Eddy	1916	Imhoff tanks, etc.
Gloversville, N. Y.	378,000.00	.....	15.26	H. P. Eddy	1916	Sedimentation tanks and filters.
Clinton, Mass	149,000.00	18,700	7.96	H. P. Eddy	1916	Sand filters and pumping station.
Lebanon, Pa.	80,000.00	17,500	4.57	P. A. Volckner	1916	Does not include outfall sewer.
York, Pa.	194,463.58	30,000	6.48	J. K. Geisey	1916	Includes outfall sewer and sand filters.
West Chester, Pa.	162,000.00	12,000	13.50	N. R. Rambo	1915	Includes outfall sewer and pumping station.
Indiana, Pa.	40,000.00	8,000	5.00	Metcalf & Eddy	1914	Plant only.
Typical plant	431,710.00	55,000	7.85	H. P. Eddy	1916	Imhoff tank and trickling filter. No trunk line sewer.
Typical plant	313,880.00	55,000	5.71	H. P. Eddy	1916	Activated sludges. No trunk line sewer.
Electrolytic plant	219,050.00	55,000	3.99	Landreth	1916	Does not include outfall sewers.

* Estimated.

In the operation of this electrolytic process it is imperative to have skilled labor in constant attendance, although the duties imposed upon it are light. However, in this process the number of units can be largely increased without any appreciable increase in the amount of labor necessary to operate the enlarged plant. This is illustrated by the data contained in Table VI showing comparisons between the operating costs of 2,000,000 gallon and 10,000,000 gallon plants.

In Table VII is given the cost of construction of various sewage disposal plants in the United States. It has not been possible in this table to indicate in every case the actual cost of the disposal plant alone, eliminating property values, trunk lines, costs, etc., and on that account the per capita costs show such great variations. It is evident, however, that the per capita cost of the construction of a Direct Oxidation plant compares favorably with that of any other process.

The data in Table VIII indicate the actual cost of operation per capita of a number of sewage disposal plants in the United States with the additional costs for interest and depreciation. An examination of this table indicates that the economy resulting from the use of the Landreth Direct Oxidation process is effected largely through a saving in the cost of construction.

Fire Engines and the Essentials of Fire Fighting. CHARLES H. FOX. (*The American Society of Mechanical Engineers,* Spring Meeting, June, 1919.)—Steam power was not successfully applied to fire engines until the beginning of the year 1853. Up to that time the so-called "hand engines" were used exclusively and it should also be understood that at that time the present-day system of water-works, was still in its infancy and, therefore, the chief dependence for a supply of water for fire-extinguishing purposes was upon methods of storage in vogue before water mains came into general use.

The conventional hand fire engine of that day comprised a rectangular wooden box suitably mounted on four low wheels. Pumps, of the piston type, were housed within and firmly fixed to the floor of the box; working levers were provided and motion was imparted to the pistons by a host of firemen lined up on opposite sides of the apparatus. At this early period fire hose was not plentiful, the best was crudely made up of leather, and the pumps were, therefore, placed close to the scene of the fire. Water, largely conveyed by a

hand-to-hand passing of fire-pails, was poured into the engine trough, where it was picked up by the pumps and forced through the leading hose and onward to be thrown on the fire. Somewhat later it became customary to equip these hand engines with a non-collapsible suction hose, so that water could be drawn directly from cisterns or wells, but the wooden tub or reservoir always remained a characteristic feature of these old-time machines.

Early in January, 1853, Mr. A. B. Latta successfully tested his new steam-driven fire engine. Mr. Latta was a citizen of Cincinnati and although his pioneer effort resulted in the production of an extremely heavy machine, the engine was purchased by the city and known as the Joe Ross. The first steamer marked the beginning of a new epoch in fire fighting.

Latta's second steam fire engine was built and installed in the year 1853. The purchase of this machine was made possible by popular subscription and the engine was named and long known in Cincinnati as the Citizens' Gift.

When fire must be fought, fire streams can be effective only when the water is expelled from the nozzle at an appropriate speed. In other words, unless enough of the initial pressure available for starting the flow through the hose survives at a point immediately back of the nozzle orifice, the resulting jet will not measure up to its mission. The characteristics of a fire stream—good, bad, or indifferent—are directly dependent upon the velocity of the jet and obviously the velocity is proportionate to the surviving pressure just mentioned. For the best results the flow may be too slow, while, on the other hand, disappointment will follow when the velocity of discharge goes beyond what might be termed the maximum economical limits of nozzle pressure.

The function of a fire engine is either to draw water from any basin or other conveniently located source or, when fire hydrants are available, to make up the pressure, which is seldom high enough in ordinary water mains to serve for effective fire service. In fighting fire, it is not uncommon to elevate the nozzle far above the source of the water supply. This procedure, of course, involves loss of forcing pressure, which is in proportion to the static head of the column. The greatest power-absorbing medium between the source of supply and the point of discharge is the fire hose. In may also be said that here is involved the point which is least understood in the subject of hydraulics as applied to fire-fighting practice.

SOME REMARKS CONCERNING THE HEAT TREATMENT OF STEEL AND THEIR APPLICATION TO THE TREATMENT OF STEELS USED FOR AIRPLANE MOTORS.* [1]

BY

ALBERT SAUVEUR, S.B.

Professor of Metallurgy and Metallography, Harvard University.
Recently Director of Metallurgy in the Air Service, A. E. F.

In heat treating rolled or forged steel we seek generally:

1. To increase its softness, that it may be more readily machined;

2. To make it strong, that it may resist successfully the stresses to which it will be subjected in use;

3. To make it hard, that it may resist wear or acquire cutting properties.

The corresponding heat treatments may be therefore described respectively as:

(*a*) SOFTENING TREATMENT,
(*b*) STRENGTHENING TREATMENT,
(*c*) HARDENING TREATMENT.

The Softening Treatment, which usually consists in cooling the metal slowly from a temperature exceeding its critical range, generally imparts to it its maximum ductility but materially reduces its strength (and elastic limit).

It is also highly beneficial in removing the strains resulting from the working of the metal. These strains are the more serious and detrimental the lower the temperature at which the metal was worked. If it has been cold worked, the necessity of removing them becomes imperative, as a strained metal is a dangerous one, inclined to be brittle and having reduced resistance to shock and to fatigue stresses.

The Strengthening Treatment implying, as it generally does, a rapid cooling from a temperature but slightly above the critical range of the metal, is not as effective as the softening treatment in removing working strains. It follows from these considera-

* Communicated by the Author.

[1] A few copies of these remarks were printed for private circulation in February, 1918, as Bulletin M 3, "Notes on the Metallurgy of Aviation," by the Technical Section, U. S. Air Service, American Expeditionary Forces.

tions that it is often advisable to subject to a softening treatment certain steel objects already soft enough to be readily machined or which are to be subjected to a strengthening treatment, for the purpose of removing thoroughly the objectionable strains created by the working operation.

The softening treatment should be logically applied after rolling or forging but before machining.

The strengthening treatment consists usually in cooling rapidly through the critical range and may be followed, as later explained, by a second heating below that range.

Roughly speaking, the strength imparted will be the greater, the quicker the cooling through the range. Increased strength moreover generally implies increased elastic limit, a property which is in reality of greater moment than mere tenacity, for, obviously, it is not intended that steel parts should ever be strained above their elastic limit, that is, until permanent distortion actually occurs.

The strengthening treatment, on the other hand, generally decreases the ductility of the metal and may result in actual brittleness. Broadly stated, the greater the increase of strength, the greater generally the decrease of ductility, that is, the greater the danger of producing a brittle metal; hence the necessity, in most cases, of being satisfied with such strengthening treatment as will yield, not maximum strength, but such strength as can be combined with the amount of ductility necessary for safety, that is, to guard us against sudden rupture under shock. If, for instance, the cooling through the range has been so rapid as to yield very great strength but very little ductility, a second treatment will be required in order to increase the ductility, while necessarily decreasing the strength.

The rapid cooling through the range which the strengthening treatment generally implies is, moreover, beneficial in destroying, in part at least, the structural orientation generally imparted to steel by work. An objectionable effect of this orientation is to cause the metal to acquire physical properties when tested in the direction of the work markedly different from those it possesses when tested at right angle to that direction. In the former case, for instance, the ductility as measured by the elongation is, as a rule, considerably greater. This implies a lack of physical or structural homogeneity obviously undesirable.

Again, the strengthening treatment generally increases in a

marked degree the hardness of the metal, and hence, imparts to the treated parts greater resistance to wear. Great softness then, cannot be generally combined with great strength, nor great strength with much ductility. Softening and strengthening treatments must necessarily be distinct and generally of opposite nature, the former implying slow cooling through the critical range, the latter a more rapid cooling. Moreover, the maximum strength the metal is capable of acquiring can seldom be utilized because of the lack of ductility, if not actual brittleness, which accompanies it.

The strengthening operation must be so conducted as to yield such combination of strength and elastic limit with ductility, as will meet the requirements of the case.

The Hardening Treatment, like the strengthening treatment, consists in cooling rapidly through the critical range.

In hardening steel, however, the primary requirement is to produce very great hardness, while overlooking the decrease of ductility implied. Indeed, as a rule, we use all possible means to hasten the cooling because of the greater hardness resulting.

Even when implements are to be hardened and thereby deprived of much of their ductility, a softening treatment preceding the hardening treatment may often be applied with beneficial results because by more thoroughly removing the forging or rolling strains it will diminish the danger of cracks occurring during the quenching in the subsequent hardening treatment.

The rational methods of conducting these three treatments may now be briefly described.

A. SOFTENING TREATMENT.

Purpose.—To soften the metal in order to facilitate machining; also to remove the strains produced by forging or rolling.

When to Apply.—After forging or rolling, but before machining.

Description.—(*a*) Heating the steel to 900° C. (1652° F.), maintaining that temperature for 30 minutes or more, cooling slowly, for instance with the furnace in which the steel was heated. (*b*) Heating to some 600–675° C. (1112–1247° F.) for several hours, cooling very slowly. (*c*) Heating to some 800–850° C. (1472–1562° F.), quenching in oil, then treatment *b*.

Treatments (*b*) and (*c*) are applicable to steels containing 0.8 per cent. carbon or more, and to some alloy steels which are not readily softened by treatment (*a*).

B. STRENGTHENING TREATMENT.

Purpose.—To increase strength and elastic limit at the sacrifice of some ductility; also to increase hardness, and, in some cases, resistance to shock and to fatigue stresses and to decrease structural orientation.

When Applied.—Generally after machining in the case of machined parts; after forging, rolling or stamping, if the objects are not to be machined.

Description.—(*a*) Heating to 50° C. (90° F.) above the critical range of the steel,[2] cooling freely in air. Steels containing less than 0.25 per cent. carbon may be quenched in oil, those with less than 0.15 per cent. carbon in oil or in water. (*b*) Heating to 50° C. (90° F.) above the critical range of the steel; quenching in water or oil (the former for low carbon steel), re-heating to 50° C. (90° F.) or more below the critical range, cooling in air, oil or water.

The rate of cooling from a temperature inferior to the critical range does not generally affect the properties of steel very materially; at least its tensile properties. The higher the temperature of the second heating the less tenacious and more ductible the metal.

Some nickel-chromium steels, however, show very low shock strength under impact testing after heating to some 600° C. (1112° F.) followed by *slow cooling* as compared to their shock strength after quenching from that temperature.

While treatment (*a*) often yields satisfactory results, treatment (*b*) affords a means of securing greater strength, as well as many different combinations of strength and ductility to meet different requirements. The steels so treated, especially certain alloy steels, are generally also more resistant to shock and to fatigue stresses. There is little if any advantage, however, in applying treatment (*b*) in preference to treatment (*a*) to carbon steels containing less than 0.25 per cent. carbon.

C. HARDENING TREATMENT.

Purpose.—To produce very great hardness while sacrificing ductility to the point of brittleness.

When Applied.—To finished parts, as a last treatment, or to be followed by grinding only.

Description.—Heating to 50° C. (90° F.) above the critical

[2] Heating steel slightly above its critical range refines the structure, heating it to a much higher temperature coarsens it.

range of the steel, cooling rapidly in water or oil, generally re-heating to 200–400° C. (392–732° F.), an operation known as tempering, which is applied in order to remove or decrease the severe strains created by the sudden cooling while losing but little hardness and to decrease brittleness. The higher the tempering temperature, the greater the softening effect of the operation.

The three basic heat treatments described above are applicable to alloy steels as well as to carbon steels bearing in mind the marked influence of some elements on the position of the critical range. Some special steels, for instance, should be heated, for the purpose of strengthening or of hardening, to temperatures considerably lower than those suitable for carbon steel, because of the lower position of their critical range. The character of the operation, however, remains the same.

Classification of Steel According to Heat Treatment Required.—According to the heat treatments required, steels may be classified as follows:

(1) Steels soft enough to be readily machined and strong enough for the stresses to which they will be subjected in service. *Heat Treatment Required.*[3]—None.

(2) Steels soft enough to be readily machined, but lacking in strength or in hardness. *Treatment to be Applied.*[3]—Strengthening treatment (*a*) or (*b*) generally after machining, and, for hardness, hardening treatment.

(3) Steels not soft enough to be readily machined but strong enough for the uses to which they are intended. *Treatment to be Applied.*—Softening treatment (*a*), (*b*) or (*c*) followed, generally after machining, by strengthening treatment (*a*) or (*b*), because the softening treatment will generally deprive the steel of much of its strength, which must then be restored.

(4) Steels neither soft enough to be readily machined nor strong enough to resist stresses in service. *Treatment Required.*—Softening treatment (*a*), (*b*) or (*c*) followed, generally after machining, by strengthening treatment (*a*) or (*b*).

It will be noted that steels of classes 3 and 4 call for similar treatments.

(5) Steel parts which should be very hard must be treated by

[3] It is important to remember that the softening treatment is also beneficial in removing the strains caused by rolling or forging and that for these reasons it may be applied with good results even to steels soft enough to be readily machined.

the hardening treatment unless they already possess great hardness, such as manganese steel and air or self-hardening steels, which will be considered later.

As already stated, it is beneficial to subject to a preliminary softening and strains—removing treatment steel parts to be hardened.

When for economical or other reasons it is advisable to subject forged or rolled carbon steel to but a single heat treatment, cooling in air from a temperature of some 800–900° C. (1472–1652° F.), according to its carbon contents, is generally to be recommended, because such treatment (1) leaves the steel in a condition generally soft enough to permit its ready machining (unless it be very high in carbon), (2) removes, in part at least, the working strains, (3) obliterates, or at least, mitigates, the structural orientation and (4) yields a fair proportion of the strength combined with a large proportion of the ductility which the metal is capable of acquiring.

HEAT TREATMENT OF CASE-HARDENED PARTS.

Case-hardened parts generally require:

1. A strengthening and toughening treatment for the core consisting in quenching from 900 to 950° C. (1652–1742° F.) followed by

2. A refining and hardening treatment of the case consisting in quenching from a temperature some 50° C. (90° F.) above the critical range, which for carbon steel would be in the vicinity of 800° C. (1472° F.). Special steels with lower critical range should, of course, be quenched from correspondingly lower temperatures. For nickel and nickel chromium steels, single quenching from some 800° C. (1472° F.) is often sufficient. After quenching for hardening the case the parts may be tempered at some 200–300° C. (392–572° F.) in order to diminish the strains and the brittleness of the case.

There are a few instances of special steels demanding treatments different from those applicable to all other steels. These exceptions should be briefly mentioned:

Manganese Steel.—A steel very hard and wear-resisting, even after slow cooling. To make it ductile, however, it should be heated to 1000° C. (1832° F.) or thereabout and quenched in water.

Self- or Air-hardening Steels.—These steels become intensely

hard on simple air cooling from a temperature of some 800 to 850° C. (1472–1562° F.). They do not therefore need any hardening treatment and they may be softened by softening treatment (*b*).

High-speed Steels.—These steels, in order to acquire their remarkable physical properties, must be heated to a very high temperature approaching the melting point of the metal and quickly cooled in air or in oil. They may then be tempered at a temperature not exceeding generally 600° C. (1112° F.). To soften these steels, in order to machine them, they may be heated to 750°–850° C. (1382°–1562° F.) for several hours and very slowly cooled.

High Nickel Steels.—That is, those containing 25 or more per cent. nickel, are softened by quenching.

APPLICATION OF THE FOREGOING CONSIDERATIONS TO THE HEAT TREATMENT OF THE STEELS USED FOR THE CONSTRUCTION OF AIRPLANE MOTORS.

Adopting the classification of the steels used in the construction of aviation motors, proposed in previous reports (Bulletins M1 and M4) the heat treatments they should receive may be inferred from the rules just outlined:

STEEL TYPE I.

Medium-hard carbon steel containing from 0.30 to 0.40 per cent. carbon. In its forged, rolled or stamped condition, this steel is soft enough to be machined. It may be nevertheless subjected to a softening treatment with beneficial results for the purpose of removing the working strains as previously explained.

With that end in view, it should be heated to 900° C. (1652° F.), kept at that temperature for 30 minutes or more, and cooled slowly. This treatment should be applied logically before machining.

After machining, and in order to increase their strength and elastic limit, as well as their resistance to shock, to wear, and to fatigue stresses, the parts should be subjected to strengthening treatments (*a*) or (*b*), bearing in mind that treatment (*b*) will yield better results than treatment (*a*) and will make it possible to obtain various combinations of strength and ductility to meet various requirements.

For treatment (*a*) heat to 850° C. (1562° F.) and cool freely

in air. For treatment (*b*) heat to 850° C. (1562° F.), quench in water or oil, reheat to 450–650° C. (842–1202° F.), according to requirements, and cool slowly or in water or oil.

STEEL TYPE II.

Low carbon steel suitable for case hardening, containing from 0.05 to 0.15 per cent. carbon. This steel in its forged, or rolled condition can be very readily machined, but it nevertheless may be subjected to a softening treatment, in order, as previously explained, to remove working strains. With that end in view, the steel should be heated to 950° C. (1742° F.) for 30 minutes, or more, and cooled slowly. This should logically be done before machining.

The case-hardened parts should then be reheated to 900° C. (1652° F.) and quenched in water or oil, in order to strengthen and toughen the core. They should then be heated to 800° C. (1472° F.) and again quenched in water or oil, in order to refine and harden the case.

They may, as a last treatment, be heated in oil to 200–300° C. (352–572° F.), in order to decrease the strains and brittleness of the case.

STEEL TYPE III.

Low carbon nickel-chromium steel, suitable for case-hardening, containing: Carbon not over 0.15 per cent.; nickel not less than 2 per cent.; chromium not less than 0.50 per cent.; and total nickel and chromium between 2.50 and 4 per cent.

While in its forged or rolled condition this steel can be easily machined, the softening treatment may be applied to remove working strains. This should be done before machining, by heating to 900° C. (1652° F.) for 30 minutes or longer, and cooling slowly.

The case-hardened parts should be:

1. Either heated to 800° C. (1472° F.) and quenched in oil or water to refine and harden the case, or

2. Heated to 900° C. (1652° F.) and quenched in order to refine and strengthen the core, followed by heating to 775° C. (1427° F.) and quenching to refine and harden the case.

After the last quenching the parts may be tempered by heating in oil at 200° to 300° C. (392–572° F.) to diminish the strains and the brittleness of the case.

STEEL TYPE IV.

Medium-hard nickel-chromium steel containing: 0.30 to 0.40 per cent. carbon; 2.50 to 3.50 per cent. nickel; 0.5 to 1 per cent. chromium; 3 to 4 per cent. total nickel and carbon.

This steel can be machined in its forged or rolled condition, but a softening treatment will increase the ease of machining and will be beneficial in decreasing the strains caused by work.

For this treatment, which should be logically applied before machining, the steel should be heated to 850–900° C. (1562 to 1652° F.) for 30 minutes or more, and slowly cooled.

The machined parts should then be subjected to a strengthening treatment consisting in heating to 800° C. (1472° F.) followed by air cooling or preferably to the double treatment consisting in heating to 800° C. (1472° F.) and quenching in water or oil, followed by reheating to 400 to 650° C. (752 to 1202° F.) according to requirements, and quenching in oil or water.

STEEL TYPE V.

Air-hardening nickel-chromium steel, containing: 0.30 to 0.50 per cent. carbon; 3.00 to 4.50 per cent. nickel; 0.50 to 2.00 per cent. chromium; and total nickel, chromium and carbon, not less than 5 per cent.

In its forged or rolled condition, this steel is difficult to machine. It should be subjected to softening treatment (*b*).

The machined parts should then be either cooled freely in air from a temperature of 850° C. (1562° F.) or quenched in oil from 800° C. (1472° F.) and reheated to 300–600° C. (572–1112– F.) according to requirements. Air cooling suffices, however, to impart great hardness and great strength to this steel.

STEEL TYPE VI.

High speed steel, suitable for exhaust valves. To soften this steel in order to permit a small amount of machining, it may be heated to 750–850° C. (1382–1562° F.) for several hours and cooled very slowly.

The valves should then be subjected to the heat treatment generally applied to high speed steel, namely:

Heating to a temperature of some 1200° C. (2192° F.) and cooling in air or in oil. This may be followed by reheating to 500–600° C. (932–1112° F.).

Method of Turning on Steam in Large Lines. (*Power,* vol. 1, No. 3, p. 124, July 15, 1919.)—Accidents and consequent losses, both direct, and indirect, due to the failure of steam piping and fittings while being cut into service when steam is being turned in, have apparently all been due to expansion strains rather than pressure strains. The expansion strains which caused the damage were usually different from those which were present after the line had been heated to full temperature.

A further analysis discloses the fact that the particular form of expansion causing the trouble has been in most cases due to the presence of air in the steam line at the time steam was being turned on. Air, having approximately twice the density of steam, remains at the bottom of the pipe and prevents the steam from coming in contact with (and thereby expanding) parts of the piping. On a straight run of horizontal piping the result has a tendency to "rainbow" the piping. This has been proved by actual test. The further result of this action is to put a heavy compression strain on the upper half of all joints and fittings and a corresponding tensile strain on the lower half. This trouble is experienced to a greater extent with large than with small piping. This may be due either to the pipe being so small that the air and steam do not remain stratified, or possibly to the great flexibility of the small piping.

The method of turning on steam, which will prevent trouble of this kind, is as follows:

All drains and air vents on the line are opened. Steam is turned into the line very rapidly, the valve being opened one-fourth to one-half its full opening. This applies not only to low pressure, but to high pressure as well. This procedure results in driving the air out of the line very rapidly and allows the pipe to heat uniformly. To engineers who have been accustomed to "warming up" slowly, or "soaking" the line, this method will no doubt seem dangerous, but the results obtained from close observation and actual test indicate that it is the best that can be followed.

The same phenomena take place in starting up a steam turbine. In the Parsons type of machine where the blade and clearances are small, the "warming up" method of starting is likely to cause blade failures, because when a machine is standing still, the spindle and cylinder "rainbow" in the same direction, but as soon as the spindle revolves one-half a revolution, the top of the spindle (then at the bottom), unless the clearances are large, rubs the bottom of the cylinder. The new method is to open the throttle quickly until the spindle starts to revolve, after which the throttle is almost closed again, allowing the turbine to revolve slowly until the heat is evenly distributed.

GIMBAL STABILIZATION.*

BY

V. BUSH, Eng.D.

Research Laboratories, American Radio and Research Corporation.

GENERAL.

THE following is an analysis of the effectiveness of gimbals of various designs for maintaining a horizontal platform on shipboard, and of gyroscopic stabilizing of such devices.

Gimbals can never maintain a platform absolutely horizontal, for there always will be a certain deviation.

The motion of the ship in the waves can affect the gimbals in three ways, namely by reason of (1) horizontal motions impressed upon the support, (2) vertical motions impressed upon the support, and (3) tipping of the support.

If the friction of the gimbals about the pivots is small, as must always be the case in a good design, the third effect is entirely negligible. The second effect comes in only when the supported platform deviates from the horizontal. If the angle of deviation is small, as it must be in a case of practical value, the second effect is also negligible. There remains to be considered only the first point, the effect of moving the support horizontally. It is sufficient to consider a single plane only, as motions at right angles produce independent effects. The to and fro motion of the support, due to rolling or pitching of the ship in a sea, is not strictly harmonic. It is usually a rough beat motion which can be considered the sum of two sinusoidal motions of somewhat different frequencies. Each of these may be considered separately if desired. To a first approximation, however, it is sufficient to consider a simple harmonic horizontal motion of the support. Obviously the motion of the gimbals does not react appreciably to affect the motion of the ship, hence we may consider the motion of the support to be an undisturbed sinusoidal oscillation.

PENDULUM.

The above problem is hence the problem of considering the motion of a physical pendulum of which the support is given a sinusoidal horizontal motion.

In Fig. 1, we have such a pendulum located by the coördinates

* Communicated by the Author.

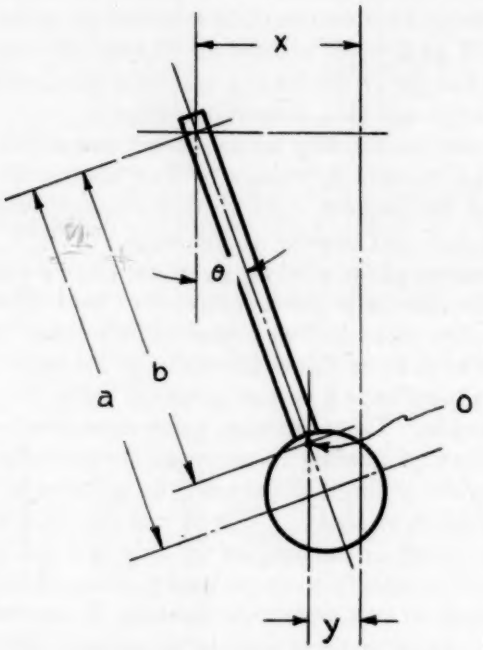
x and θ, where x is caused to vary in accordance with the expression

$$x = A \sin \omega t$$

The pendulum has constants

m = total mass
b = length from centre of mass to support
a = radius of gyration

FIG. 1.



It will also be convenient to use the coördinate y, which for the small values of θ to be considered throughout is given by

$$y = x - b\theta$$

ANALOGOUS ELECTRICAL CIRCUIT.

The formulas for forced harmonic motions of electrical circuits are in much more convenient form than the formulas for mechanical systems. It will accordingly be convenient to solve first the electrical circuit which is analogous to the mechanical system of our problem, and then to interpret the results on the problem itself.

We will consider first the simple pendulum in which

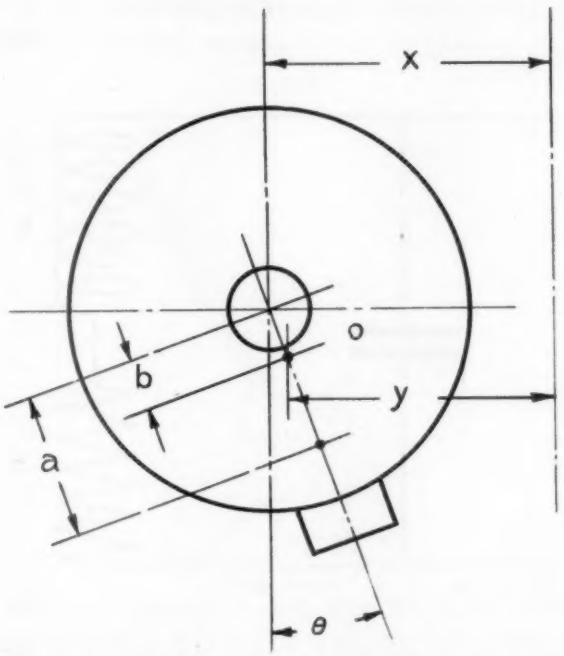
$$a = b$$

Such a pendulum when the support is moved in accordance with

$$x = A \sin \omega t$$

is analogous to the series electrical circuit of Fig. 3, containing resistance R, inductance L and capacity C, when independently

FIG 2.



of the circuit a charge is supplied to the condenser in accordance with

$$q = Q \sin \omega t$$

This will be true when we have in a pair of leads connected across the condenser, the current

$$i = \frac{dq}{dt} = Q\omega \cos \omega t$$

Using the vector notation this would be written

$$I = j\,Q\omega$$

If I_1 is the vector current in the inductance, we may write the relation between I_1 and I by considering that I divides into parts proportional to the admittances of the two branches. That is

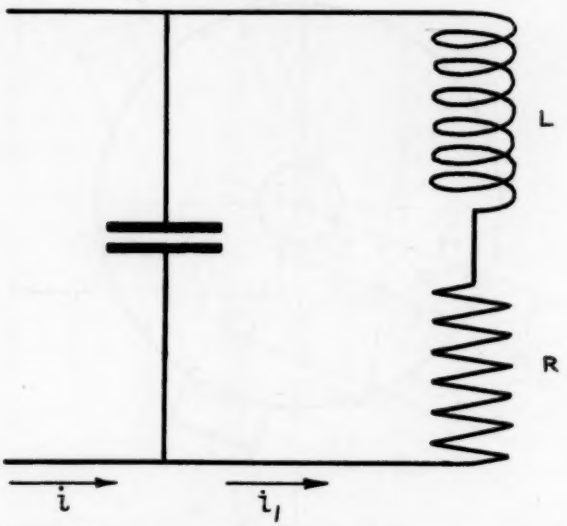
$$I_1 = I \frac{\frac{1}{jC\omega + \frac{1}{R + jL\omega}}}{R + jL\omega} = I \frac{1}{1 - LC\omega^2 + jRC\omega} = \frac{jQ\omega}{1 - LC\omega^2 + jRC\omega}$$

TRANSFER TO MECHANICAL SYSTEM.

Considerable care must be used, in interpreting this result on the mechanical system, to obtain exact analogues.

We have already set the maximum quantity Q analogous to

FIG. 3.



the maximum displacement A. Hence the current in the leads is analogous to $\frac{dx}{dt}$ or $\dot{x}$. If a displacement A is produced, and the centre of mass is simultaneously prevented from leaving the centre line, there will be, for a small angle θ, a back force produced equal to $\frac{mg}{b} A$, as can be seen from Fig. 4. Analogously in the electrical circuit if a charge Q is introduced through the mains, and the branch circuit is open so that this affects the condenser only, there will be a back electromotive force $\frac{Q}{C}$. We thus have C analogous to $\frac{b}{mg}$.

The kinetic energy of the mechanical system in the case of a pendulum with concentrated bob is

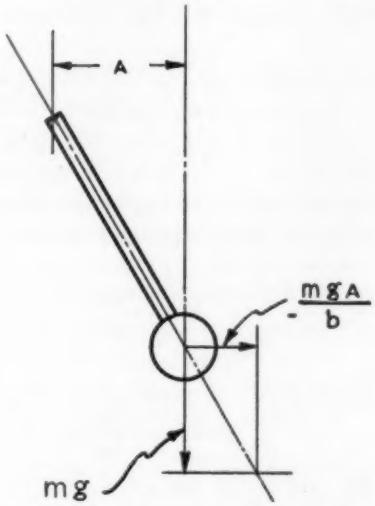
$$\frac{m\,(\dot{x}-b\dot{\theta})^2}{2}$$

and the energy stored in the magnetic field of the electrical system is

$$\frac{Li_1^2}{2}$$

Hence L and m are analogous; and i_1 corresponds to $(\dot{x} - b\dot{\theta})$ or $\dot{y}$, that is to the net horizontal speed of the centre of the bob.

FIG. 4.



The frictional constant F, which is the force which occurs when the bob moves at unit net constant speed, corresponds to the resistance constant R which is the force arising when unit steady current flows in the branch circuit.

We may make the analogy more apparent by writing the differential equations for the two systems.

For the mechanical system, equating the forces on the bob, we have

$$m\,\ddot{y} + F\,\dot{y} = m\,g\,\theta$$

which may be arranged

$$m\,\ddot{y} + F\,\dot{y} + \frac{mg}{b}\,y = \frac{mg}{b}\,A \sin \omega t$$

For the electrical system, summing the voltages about the circuit

$$L\,\dot{i}_1 + R\,i_1 + \frac{1}{C}\int (i_1 - i)\,dt = 0$$

which becomes upon differentiating and substituting

$$L\,\ddot{i}_1 + R\,\dot{i}_1 + \frac{1}{C}\,i_1 = \frac{1}{C}\,Q\omega\cos\omega t$$

Place side of this the derivative of the equation for the mechanical system

$$m\,\dddot{y} + F\ddot{y} + \frac{mg}{b}\,\dot{y} = \frac{mg}{b}\,A\omega\cos\omega t$$

and we may read off immediately the analogies

$\dot{y}$	i_1
m	L
F	R
$\frac{b}{mg}$	C
A	Q

Inserting these quantities in the expression above for the electrical circuit, we obtain for the mechanical system

$$\dot{y} = \frac{jA\omega}{1 - \frac{b\omega^2}{g} + j\,\frac{Fb\omega}{mg}}$$

or

$$y = \frac{A}{1 - \frac{b\omega^2}{g} + j\,\frac{Fb\omega}{mg}}$$

and since $y = x - b\theta$, and $x = A\sin\omega t$,

$$\theta = \frac{1}{b}\left(A - \frac{A}{(1 - \frac{b\omega^2}{g}) + j\,\frac{Fb\omega}{mg}}\right)$$

We are interested in the maximum value to which θ attains, and hence in the maximum value of the above vector expression, which becomes when simplified

$$\theta_{max} = \frac{A}{b}\,\frac{\sqrt{\left[\left(1 - \frac{b\omega^2}{g}\right)^2 - \left(1 - \frac{b\omega^2}{g}\right) + \left(\frac{Fb\omega}{mg}\right)^2\right]^2 + \left(\frac{Fb\omega}{mg}\right)^2}}{\left(1 - \frac{b\omega^2}{g}\right)^2 + \left(\frac{Fb\omega}{mg}\right)^2}$$

This formula checks dimensionally, thus affording an indication that the substitutions have been made correctly.

When the frictional force is zero it reduces to

$$\theta max = \frac{A}{b - \frac{g}{\omega^2}}$$

These formulas hold only for small values of θ, and the absolute value of the result should be considered irrespective of sign.

When there is resonance, that is when the period of oscillation is the same as the natural period of the pendulum, which will occur when

$$\omega = \sqrt{\frac{g}{b}}$$

we have

$$1 - \frac{b\omega^2}{g} = O_1$$

and the formula shows that a large angle may result from even a small amplitude of oscillation of the support. On the other hand, when b is very long, the angle of deviation is nearly zero.

In the above the frictional force is assumed proportional to $\dot{y}$, that is to the net velocity of the bob through the medium; and the friction of the pivot is considered negligible, as must be the case if tipping of the support is not to affect the pendulum. In many practical cases it is nearer the truth to consider the frictional force to be proportional simply to $b\dot{\theta}$, that is to consider that the medium moves with the support.

If this assumption is made, the differential equation for the mechanical system becomes

$$m\ddot{y} + F\dot{y} + \frac{mg}{b}y = \frac{mg}{b}A\omega\cos\omega t - FA\omega^2\sin\omega t$$

In Fig. 3, if we alter the current leads to be connected across the coil alone, instead of the coil and resistance, the equation for the circuit becomes

$$L\ddot{i}_1 + R\dot{i}_1 + \frac{1}{C}i_1 = \frac{1}{C}Q\omega\cos\omega t - RQ\omega^2\sin\omega t$$

The same analogy thus holds as before, and if this new circuit be solved, and the substitutions made, we obtain for the maximum deviation for the assumption that the medium moves with the pivot:

$$\theta max = \frac{A}{\sqrt{\left(b - \frac{g}{\omega^2}\right)^2 + \left(\frac{Fb}{m\omega}\right)^2}}$$

which reduces, upon setting $F = o$, to the same simple formula for the frictionless case.

PHYSICAL PENDULUM.

We will now consider the case where all of the mass cannot be considered as concentrated at a point, as is the case for the systems shown in Figs. 1 and 2.

The peculiarity of this case is that there may be kinetic energy stored in the system even when the centre of mass is not moving. If x and θ are both increasing in such a manner that

$$\dot{y} = \dot{x} - b\dot{\theta}$$

is zero, there still is a kinetic energy of rotation about the centre of mass. If "a" is the radius of gyration about the pivot, the radius of gyration about the centre mass at a distance "b" from the pivot will be

$$\sqrt{a^2 - b^2}$$

and the above kinetic energy will hence be equal to

$$m \frac{(a^2 - b^2)\ \dot{\theta}^2}{2}$$

Consider now the circuit of Fig. 5, in which there is added the inductance "l" in series with the condenser. The circuit may store energy in a magnetic field even when there is no current in the branch circuit, that is when

$$i_1 = o\ .$$

An analogy with the mechanical system may be set up for this circuit exactly as before, and by the same reasoning as above used we have

Electrical	Mechanical
Q	A
i	x
i_1	$\dot{x} - b\dot{\theta}$
i_2	$b\dot{\theta}$
C	b/mg

Now when $i_1 = o$, the energy in the magnetic field is

$$l \frac{i_2^2}{2}$$

and we see that if this is to correspond to the kinetic energy above when i_2 is set equal to $b\dot{\theta}$ we must have

Electrical	Mechanical
l	$m \frac{a^2 - b^2}{b^2}$

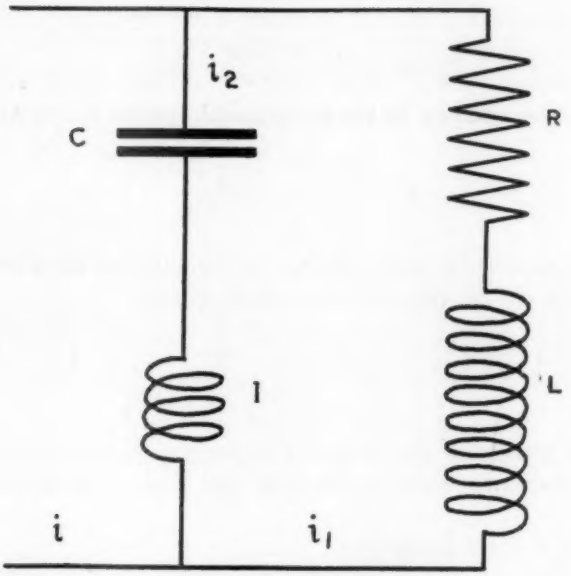
If now $b\dot{\theta}$ is taken as zero so that we have simply translation, the

kinetic energy is $\frac{m\dot{x}^2}{2}$. Also, if i_2 is zero so that $i = i_1$, the magnetic energy is $\frac{Li^2}{2}$, and since i and $\dot{x}$ are analogous, we have

Electrical	Mechanical
L	m

as before.

FIG. 5.



We may check the consistency of our analogy as follows: In the electrical system assume $i = o$, and hence $i_1 = i_2$. The magnetic energy is

$$\frac{(L + l)\, i_2^2}{2}$$

Similarly in the mechanical system, assume the pivot at rest, and the pendulum simply rotating. The kinetic energy is then

$$m\,\frac{a^2\dot{\theta}^2}{2}$$

Hence we must have the analogy	$L + l$	$\frac{ma^2}{b^2}$
But we already have	l	$m\,\frac{a^2 - b^2}{b^2}$
so that we must have	L	$m\,\frac{a^2}{b^2} - m\,\frac{a^2 - b^2}{b^2}$
but this reduces to simply	L	m

as before, giving us a check on the analogy as far as this part of the circuit is concerned.

Now in the electrical system we have

$$I_1 = I \frac{\dfrac{1}{\dfrac{1}{jl\omega + \dfrac{1}{jC\omega}} + \dfrac{1}{R + jL\omega}}}{R + jL\omega}$$

$$= jQ\omega \frac{1 - lC\omega^2}{1 - (l + L)C\omega^2 + jRC\omega}$$

Hence by analogy in the mechanical system we have

$$Y = \frac{jA\omega\left(1 - \dfrac{a^2 - b^2}{b - g}\right)\omega^2}{1 - \dfrac{a^2\omega^2}{bg} + j\dfrac{Fb\omega}{mg}}$$

and from this by the same process of reduction as used before, we may obtain for the case of the medium at rest:

$$\theta max = \frac{A}{B} \frac{\sqrt{\left[\left(1 - \dfrac{a^2\omega^2}{bg}\right)^2 - \left(1 - \dfrac{a^2\omega^2}{bg}\right)\left(1 - \dfrac{a^2 - b^2}{be}\omega^2\right) + \left(\dfrac{lb\omega}{mg}\right)^2\right] + \left(\dfrac{Fb\omega}{mg}\right)^2\left(1 - \dfrac{a^2 - b^2}{bg}\omega_2\right)^2}}{1 - \left(\dfrac{a^2\omega^2}{bg}\right)^2 + \left(\dfrac{Fb\omega}{mg}\right)^2}$$

It will be noted that this formula reduces to the one derived for a simple pendulum when $a = b$, and also that it is dimensionally correct.

When $F = o$ it reduces to

$$\theta max = \frac{A}{\dfrac{a^2}{b} - \dfrac{g}{\omega^2}}$$

This formula is particularly interesting in showing that when $\frac{a^2}{b}$ is large, that is with a pendulum of large radius of gyration, mounted only slightly away from its centre of mass, the angle of deflection will be very small. Also resonance may be obtained exactly as before, the frequency of oscillation in this case being

$$\frac{1}{2\pi}\sqrt{\frac{gb}{a^2}}$$

GYROSCOPIC STABILIZATION.

The effect of a very long pendulum may be obtained in an instrument of small dimensions by the use of the gyroscope.

An arrangement of this sort is shown in Fig. 6. The size and

speed of gyro, and the strength of the restoring spring, determine the constants of the equivalent pendulum.

Assume first that the weight of the frame can be neglected in comparison with the gyro.

Let the gyro be of such size and speed that a unit torque about the pivot causes precession at the rate of p radians per second. Let the spring be of such strength that a displacement of the gyro of one radian brings to bear on the gyro a restoring torque s. Let the centre of gravity of the system be a distance c below the pivot, and let the mass of the system be M.

FIG. 6.

Consider the system initially displaced through a small angle ϕ, the gyro being in mid position. A torque $Mgc\phi$ acts on the gyro, and it precesses at a rate

$$Mgcp\phi \text{ radians per second.}$$

The spring then exerts a restoring torque

$$s\int Mgcp\phi\, dt$$

and under its influence the gyro precesses about the pivot at a rate

$$Mgscp^2\int \phi\, dt \text{ radians per second.}$$

That is

$$\frac{d\phi}{dt} = - Mgscp^2\int \phi dt$$

or

$$\frac{d^2\phi}{dt^2} = - Mgscp^2\phi$$

The pendulum will then oscillate in accordance with the formula

$$\varphi = \varphi_0 \sin p\sqrt{Mgsc}t$$

If b is the length of the centre of gravity of the equivalent physical pendulum, and a is its radius of gyration we have

$$\sqrt{\frac{gb}{a^2}} = \sqrt{g(Mscp^2)}$$

from which

$$\frac{a^2}{b} = \frac{1}{Mscp^2}$$

Disregarding friction we may then write for the maximum deviation of the pendulum from the vertical when the support is moved harmonically a distance A either side of the centre position

$$\theta max = \frac{A}{\frac{a^2}{b} - \frac{g}{\omega^2}}$$

or

$$\theta max = \frac{A}{\frac{1}{Mscp^2} - \frac{g}{\omega^2}}$$

The rate of precession of a gyroscope is given by

$$\psi = \frac{T}{IV}$$

where

ψ is the angular velocity of precession,
I is the polar moment of inertia of the wheel,
V is the angular velocity of the wheel,

and

T is the applied torque.

Letting

$$T = 1$$

we have

$$p = \frac{1}{IV}$$

from which

$$\frac{a^2}{b} = \frac{I^2V^2}{Msc}$$

and thus

$$\theta max = \frac{A}{\frac{I^2V^2}{Msc} - \frac{g}{\omega^2}}$$

In order to find a, assume the pendulum to be hanging vertically, with the gyro in its mid position. Suppose now we apply a torque T to deflect the pendulum from its central position. The gyro first precesses at a rate

$$\psi = \frac{T}{IV} \text{ radians per second,}$$

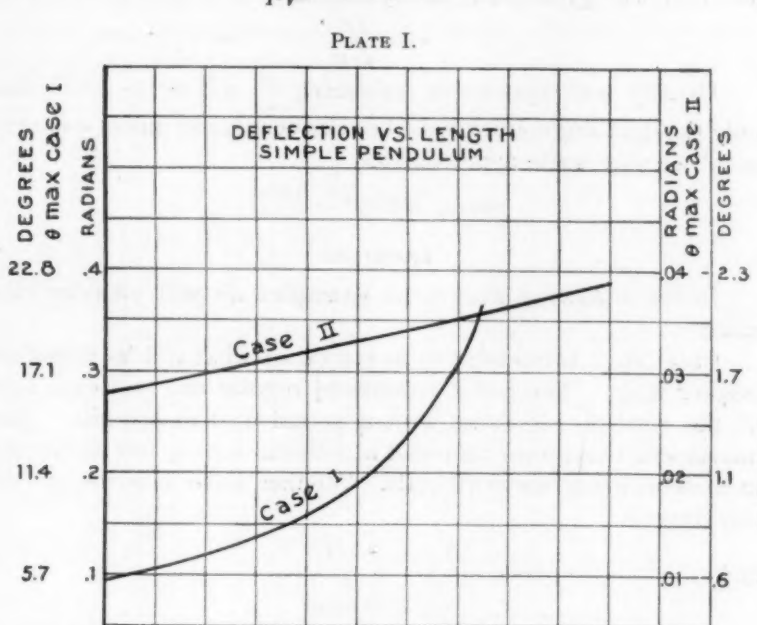
whereupon the restoring spring exerts a restoring torque equal to

$$\frac{sTt}{I^2V^2}$$

which in turn results in a precession in the direction of the applied torque at a rate

$$\frac{sTt}{I^2V^2} \text{ radians per second.}$$

PLATE I.



The angular acceleration is thus

$$\frac{sT}{I^2V^2}$$

If we consider a physical pendulum of mass M and radius of gyration a acted upon by torque T, the angular acceleration will be

$$\frac{T}{Ma^2}$$

Hence we have

$$a^2 = \frac{I^2V^2}{sM}$$

and since from the above

$$\frac{a^2}{b} = \frac{I^2V^2}{sMc}$$

it follows that

$$b = c$$

Thus the effect of the gyroscope is simply to cause the equivalent radius of gyration of the system to be increased to the value

$$a = \frac{IV}{\sqrt{sM}}$$

Usually with gyroscopic stabilizing $\frac{g}{\omega}$ will be so small that only the gyroscopic effect need be considered, and unless ω is very small we may write approximately

$$\theta max = AMscp^2 = \frac{AMsc}{I^2V^2}$$

EXAMPLES.

In the following illustrative examples we will consider two cases.

Case No. 1 is intended to be typical of what will be found on smaller boats. The roll is considered regular and 30° each side of the vertical, occurring with a period of five seconds. The instrument is assumed mounted at a distance of 4 feet above the axis about which the craft rolls. We then have in terms of feet and seconds

$$A = 2 \quad \omega = 2\pi .2$$

and

$$x = 2 \sin 1.256t$$

Case No. 2 is intended to represent a large ship. The roll is considered to be 15° either side, with a period of 15 seconds, the instrument mounted 20 feet above the centre of roll.

Then

$$A = 5.2 , \quad \omega = \frac{2\pi}{15}$$

and

$$x = 5.2 \sin .418t$$

SIMPLE PENDULUM.

Consider first a simple pendulum, and neglect friction. The maximum angle of deviation is given by

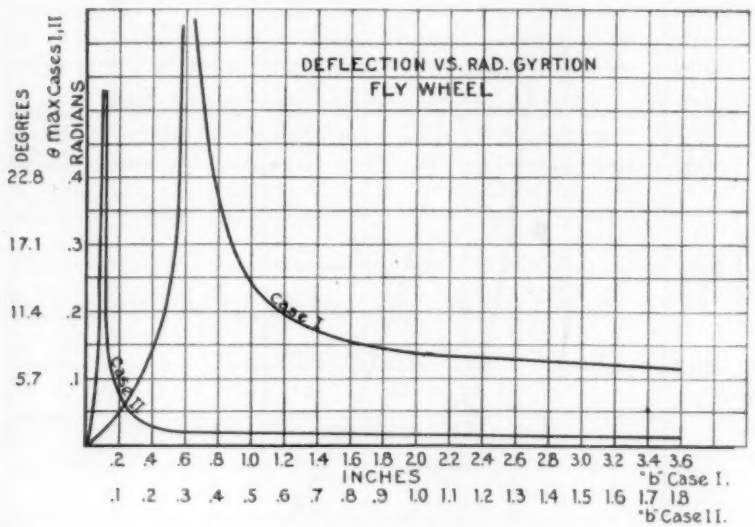
$$\theta max = \frac{A}{b - \frac{g}{\omega^2}}$$

The results of computation for various values of b are plotted on Plate I for the two cases above.

The curves show that in Case No. 1 a pendulum of reasonably short length will deflect about 5 degrees while a pendulum 15 feet long will deviate an amount greater than twenty degrees, so much in fact that the formulas no longer hold even approximately.

In Case No. 2 the deflection for a short pendulum will be about 1.5 degrees, this deflection becoming large as the length of pendulum approaches 183 feet.

PLATE II.



This example shows conclusively that a simple pendulum of reasonable length swung in frictionless gimbals on board ship cannot be expected to remain vertical within several degrees.

PHYSICAL PENDULUM.

As a second example consider a fly wheel with heavy rim swung slightly off centre. Suppose the radius of gyration, which will be approximately the mean radius of the rim, to be 1 foot, and disregard friction.

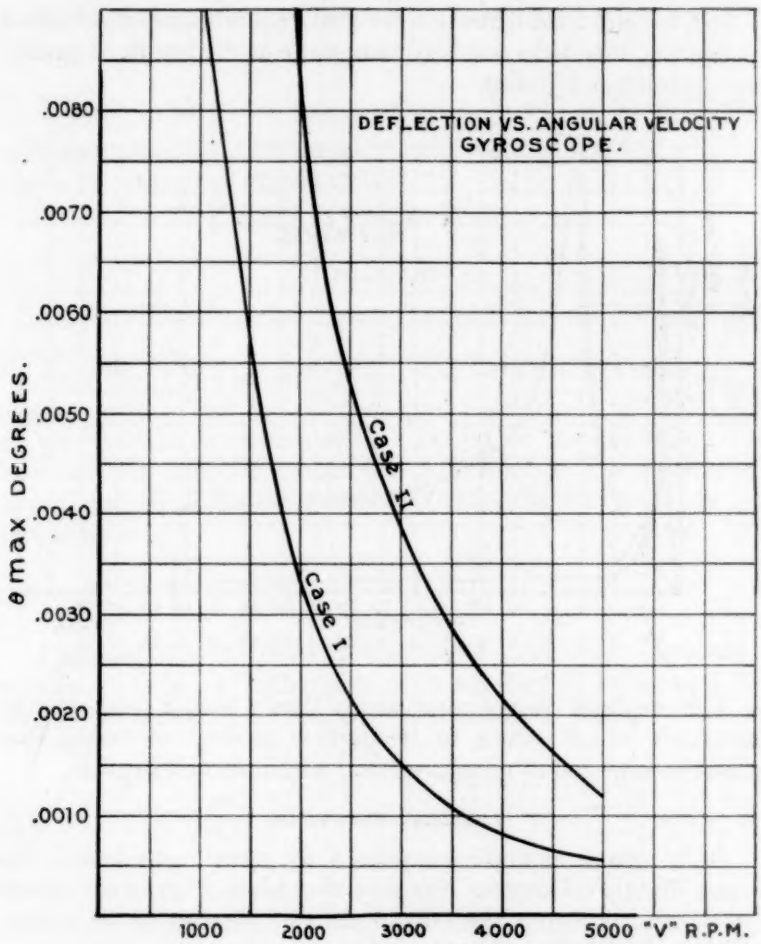
The formula now is

$$\theta max = \frac{A}{\frac{a^2}{b} - \frac{\omega^2}{g}}$$

On curve sheet 2, are plotted the results with this fly wheel suspended various distances off centre.

Considering Case No. 1 we see that when the distance off centre is several inches, the deviation is several degrees, as with

PLATE III.



the simple pendulum. If the eccentricity is shortened the angle becomes larger, and at one inch is about 15 degrees. If "*b*" is made very small, however, conditions improve, and when *b* is .12 inches the deflection is 1.4 degrees. If *b* is made .01 inches

the deflection will be in the neighborhood of .1 degree. In this latter case, however, there would not be probably enough eccentricity to properly overcome friction. For Case No. 2 conditions are even less favorable. It will thus be seen that even using a massive pendulum it would be difficult to design in such a manner that very small deflections would result.

USE OF GYROSCOPE

Let us now consider the use of the gyroscope for stabilizing. Suppose the gyro wheel to weigh 1 pound, with a radius of gyration of .25 feet, revolving at speeds up to 5000 *r. p. m.* Suppose the mass of the whole system to be two pounds, with a centre of gravity .5 feet below the support. Suppose the restoring spring to be of such strength that when the gyro is deflected through 1 radian or 57 degrees it exerts a force of .05 pounds at a lever arm of .1 foot.

Then

$$\begin{aligned} c &= .5 \\ M &= 2 \\ s &= .005 \end{aligned}$$

The formula is

$$\theta max = \frac{A}{\frac{I^2 V^2}{Msc} - \frac{g}{\omega^2}}$$

and for the values of the example:

Case No. 1

$$\theta max = \frac{2}{.78 V^2 - 20.4}$$

Case No. 2

$$\theta max = \frac{5.2}{.78 V^2 - 183.6}$$

On Plate III are plotted curves for this example for speeds up to 5000 *r. p. m.*, that is up to

$$V = \frac{2 \pi 5000}{60} = 524 \text{ radians per second.}$$

It will be noted that at this highest speed the maximum deflection in the two cases is .0005 and .0014 degrees, respectively. Thus practically complete stabilization is obtained.

MEDFORD HILLSIDE, MASS.,
Nov. 8, 1918.

Hydro-Electric Development in Ontario. (*The Canadian Engineer,* vol. xxxvi, p. 529, June 12, 1919.)—Sixty thousand horsepower will be developed on the Nipigon River, about sixty miles northeast of Port Arthur, by the Hydro-Electric Commission of Ontario, and it is expected that by June of next year two 12,000 h.p. units will be in operation. Propositions from several leading water turbine builders are now being considered, and after the contract for the "wheels" is let, which may be within the next two or three weeks, definite plans will be completed and active work will be commenced at the site of the new power house.

The Nipigon River flows from Lake Nipigon to Lake Superior, a distance of about 32 miles. The normal elevation of Lake Nipigon is 852 ft., and of Lake Superior, 602 ft. There are at least four power sites on the river, all of which will ultimately be developed by the Commission. Between Lake Nipigon and Emma Lake are Virgin Falls, Rabbit Rapids and Devil Rapids, where the total head for development through Hannah Lake would be 42 ft. South of Emma Lake are Flat Rock Rapids, White Chute and Pine Portage Rapids, with a head of 55 ft. South of Lakes Maria and Jessie—near Cameron's Pool—are two sites. The upper site affords 65 ft. net head and the lower, 53 ft. The upper site at Cameron's Pool is considered to be the most advantageous one on the river, and naturally will be developed first.

The design of the proposed plant includes a regulating dam that can raise the river level to the elevation of Lakes Maria and Jessie, which will form natural storage reservoirs. It is estimated that a peak load of 60,000 h.p. can be taken care of by the normal flow, and that is the size of the plant that will be built.

The initial installation will be two units, each 12,000 h.p., but three more will be installed at a later date. Single runner vertical water turbines will be direct-connected to 3-phase, 60-cycle, 12,000-volt, internal revolving field generators, each 10,600 k.v.a. (80 per cent. factor, maximum rating). The generators will be arranged for parallel operation and will supply light, heat and industrial power on the Commission's "Nipigon System." This development is further west than any other yet undertaken by the Commission.

THE PHOTOMETRIC SCALE.*

BY
HERBERT E. IVES, Ph.D.
Member of the Institute.

INTRODUCTORY.

THE term "Photometric Scale" is here used to include, in reference to photometry, the same kind of collection of constants, fixed points, methods, etc., as, in reference to thermometry, go to establish and maintain the thermometric or temperature scale. Such a scale, rationally based, and adequately specified, is necessary in any branch of exact science, to insure agreement of results among different workers, and to give their results scientific and practical value when obtained.

A complete photometric scale has been established and published by the present writer during the past few years. It involves the following factors:

1. Conditions of observation.
2. Method of choosing observers.
3. Relative luminous values of radiant energy of various wave-lengths.
4. The value of the lumen in terms of the watt of luminous flux.
5. Standards of luminous intensity.
6. Standards of color difference.

These factors have been interchecked until complete agreement and consistency have been obtained—an essential procedure if photometric methods are to be used in accurate scientific work. As the scale now stands it provides complete and practical means for the precision measurement of the luminous values of all kinds of light sources.

Since its first publication a number of years have elapsed, in which time additional data have been collected, both by the writer and by others (notably at the Bureau of Standards), which now make it possible to fix the constants of the scale with somewhat greater exactness. It is the purpose of the present article to gather together in one place all the recommendations and data which constitute this scale, bringing them completely up to date.[1]

* Communicated by the Author.

I. CONDITIONS OF OBSERVATION.

Since the relative luminosity of the various colors is a continuously varying function of brightness and field size, it becomes necessary to choose certain conditions as standard conditions of measurement. The brightness and field size selected should be representative of useful working conditions. The measuring method should be a practical one, of as high precision as possible.

As a result of comprehensive studies the writer [2] has been led to recommend the use of a field brightness of 2.5 milli-lamberts, and a field size of two degrees diameter. This brightness is about as high as can be easily handled with the photometric standards in ordinary laboratory use. It is, however, at the lower limit of modern working illuminations, and considerably below normal daylight illuminations. This latter objection is offset by the use of the small field, which has the effect of shifting the equivalent illumination upward, so that the final condition does correspond to modern working illuminations.

A very great advantage of the choice of these conditions is that under them the extremely practical and precise flicker photometer yields (at infinitely less trouble) the same results as are derived from the less precise method of juxtaposed fields or direct comparison.[3]

The complete specifications for the conditions of observation for precision photometry on the scale under discussion are then:

A photometric field of two degrees diameter, a field brightness of 2.5 milli-lamberts. (A)

The use of the flicker photometer is recommended.[4]

II. METHOD OF CHOOSING OBSERVERS.

No agreement between different laboratories, nor useful photometric results corresponding to an average eye, can be obtained without some standardized method of picking observers whose color vision is normal or averages normal. The ideal method of choosing observers would be to obtain the luminous efficiency curve of the spectrum for each member of the laboratory staff, and pick the men to be used by comparison with an established average luminous efficiency curve. The labor involved in such a procedure makes it, however, impracticable for general use.

As an alternative simpler method, the author has proposed [5] the measurement by each prospective observer of an arbitrary

color difference whose value for the average eye has been established by numerous observations. Only those observers should be used who are normal, or who form a group which averages normal.

The color difference proposed was that furnished by placing over a "4-watt" carbon lamp two inorganic salt solutions in layers one centimetre thick, whose composition was such that the absorptions were equal for the average eye. The group to be used in any color difference measurement was then such a group that their average reading of the two solution transmissions was equality.

The original solutions were worked out on the basis of measurements made on 61 observers. At a later date, Crittenden and Richtmyer at the Bureau of Standards [6] made measurements upon about double this number of observers, and as a result found a slight change necessary in the ratio of transmissions. This in turn indicated a change of composition in order to give two solutions of equal transmission. Making this change in composition, the method of choosing observers may now be specified as follows:

Observers for making color difference comparisons shall be selecetd by measurements on two test colors. The constitution of the YELLOW test color is

72 grams potassium bichromate to one litre of water. The constitution of the BLUE test color is

57 grams copper sulphate to one litre of water.

The group of observers, preferably not less than five in number, should obtain an average value of unity for the ratio of the transmissions of these test color solutions when used over a "4-watt" carbon lamp. (B)

Details as to the technic of preparing the solutions, the choice of tanks, and the temperature coefficients, may be obtained from the original publications.[7, 8]

III. RELATIVE LUMINOUS VALUE OF RADIANT ENERGY OF VARIOUS WAVE-LENGTHS.

An essential part of the photometric scale is the relation between radiant energy and luminous energy, for all colors, or the *luminous efficiency curve of the spectrum.* Only by an exact knowledge of this can light and energy be coördinated, and photometry become a really precise branch of science. It should be

self-evident that the luminous efficiency curve must be obtained by the same photometric method as is used in the photometry of the integrated luminous fluxes.

In the scale as published by the writer the luminous efficiency curve was arrived at by empirical variation of a curve obtained by direct measurement with a limited number of observers. The

TABLE I.

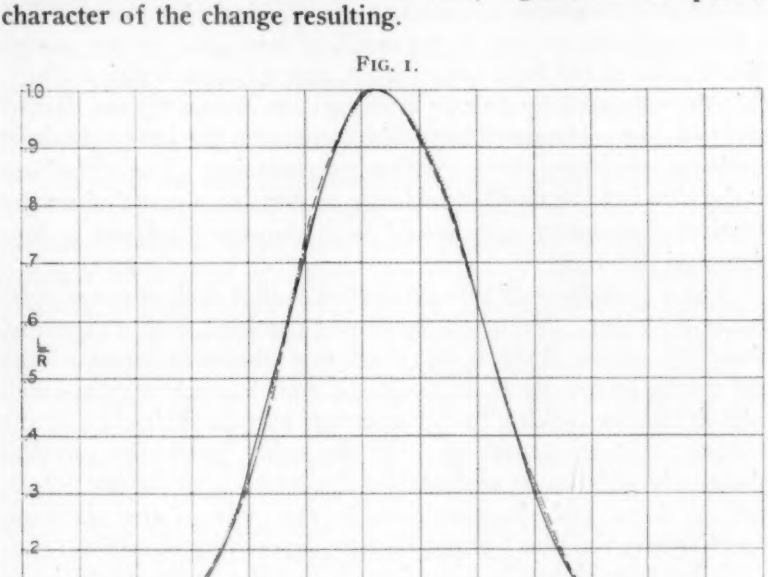
Luminous Efficiency of the Spectrum.

λ	Physical Photometer	Nutting	Calculated (3-Term Expression)
.400μ	....	.0021	.0024
.410	....	.0036	.0032
.420	....	.0065	.0096
.430	....	.0115	.018
.440	....	.022	.029
.450	....	.038	.041
.460	(.007)	.061	.058
.470	(.029)	.101	.090
.480	(.091)	.149	.138
.490	(.185)	.215	.215
.500	.317	.314	.341
.510	.478	.456	.493
.520	.652	.646	.638
.530	.799	.815	.795
.540	.911	.925	.919
.550	.985	.986	.992
.560	.999	.995	.999
.570	.957	.949	.953
.580	.888	.871	.879
.590	.782	.762	.777
.600	.639	.634	.633
.610	.494	.498	.491
.620	.365	.368	.362
.630	.261	.268	.240
.640	.170	.166	.164
.650	.094	.105	.101
.660	.051	.058	.060
.670	.029	.032	.038
.680	.014	.016	.022
.690	.008	.0081	.013
.700	....	.0036	.007

variations were made in the constitution of a " luminosity curve solution " used with a non-selective radiometer to form a precision physical photometer, and the modified curve was checked by measurements on the " test colors " and on a large range of black body colors, until it gave results completely agreeing with the visual method.

With the slight change of composition made necessary in the test color solutions by the measurements on a larger number of observers, a corresponding change was called for in the luminous efficiency curve. This was made by an empirical change in the composition of the physical photometer solution, and published some time since,[9] without, however, any figures on the spectral character of the change resulting.

FIG. 1.



Luminous efficiency of the spectrum.

Dotted line—Physical photometer solution.
Dashed line—Nutting's curve as revised.
Full line—Calculated from 3-term expression.

There has recently been made, through the courtesy of the Bureau of Standards, a precision measurement of the spectral transmission of this revised luminous efficiency curve solution. This measurement was made by both visual and photo-electric spectroradiometry, and is probably considerably more accurate, especially at the blue end of the spectrum, than the measurements made and published on the earlier solutions. The results of this measurement are listed in Table I, and are plotted (dotted line) in Fig. 1.

In comparing this with the earlier curve (which lies further toward the red) and with other published curves, the interesting fact was discovered that it almost exactly agrees with the one obtained by Doctor Nutting some years ago, using substantially the photometric method here outlined, although with a random group of 21 observers. Nutting's curve as originally published did not prove suitable as tested on the physical photometer,[10] but it has since been revised as the result of later data on the energy distribution of the light source used, and it is this revision which (kindly furnished by Doctor Nutting), as shown by the dashed curve in Fig. 1, is practically coincident with the lately obtained luminous efficiency curve solution transmission. The difference in the blue is to be decided in favor of Nutting's curve, since the physical photometer tests would be inadequate to detect a deficiency of this sort.

The significance of this agreement is that each curve supplements the other. Nutting's curve was obtained with a group of observers whose characteristics are not known in terms of the test colors, so that while its shape and end characteristics are well established, its position in the spectrum may be shifted from the average of a larger group. On the other hand, the physical photometer solution is accurately coördinated with the test colors, but its shape and characteristics at the ends of the spectrum (particularly the blue) might be only approximately right.[11]

It has been shown by Kingsbury [12] that the luminous efficiency curve of the spectrum may be well represented by a series of terms of the form

$$\frac{L}{R} = \left(\frac{\lambda max}{\lambda}\right)^n e^n \left(1 - \frac{\lambda max}{\lambda}\right)$$

Both of the curves under discussion are well represented by a three-term expression of this form with constants given below. As a consequence the formulation of the relation between the luminous values and the energy values of the spectrum may be expressed as follows:

The luminous efficiency curve of the spectrum is given by the expression (C)

$$\left(\frac{L}{R}\right)_\lambda = .977\left(\frac{.556}{\lambda} e^{1 - \frac{.556}{\lambda}}\right)^{200} + .085\left(\frac{.60}{\lambda} e^{1 - \frac{.60}{\lambda}}\right)^{1300} + .04\left(\frac{.47}{\lambda} e^{1 - \frac{.47}{\lambda}}\right)^{200}$$

The luminous efficiency curve of the spectrum is accurately copied for purposes of physical photometry by a solution of composition (D)

$Cu\ Cl_2$	61.25	grams
$Co\ (NH_4)_2\ (SO_4)_2$	14.5	grams
$K_2\ Cr\ O_4$	1.9	grams
Water to	1	liter

The original paper [10] should be consulted for details of the technic of the physical photometer.

IV. THE VALUE OF THE LUMEN IN TERMS OF THE WATT OF LUMINOUS FLUX.

The common unit of luminous flux, the lumen, is entirely arbitrary.[13] It is related to the watt of luminous flux by a constant, commonly called "the mechanical equivalent of light." The simplest method of obtaining the value of this constant is to measure in absolute units the energy transmitted by a luminous efficiency curve screen from a light source of known lumen output. This measurement has been carried through with the original luminous efficiency curve solution, giving a value for the lumen of .00160 watts. In order to correct this to the newer curve it has only been necessary to obtain the luminosity curve of a standard ("4-watt") lamp for both curves, which is easily done graphically, and measure the relative areas. Carrying through this procedure gives as the new figure .00156. The next element of the photometric scale is therefore specified as follows:

The lumen is equivalent to .00156 watts of luminous flux. (E)

V. STANDARDS OF LUMINOUS INTENSITY.

The question of a primary standard of light assumes somewhat less importance than has been accorded to it in the past, immediately luminous flux is properly analyzed into its physical part and its physiological part. The rational *unit* of luminous flux, the watt, is to be maintained by the same standards as those employed for the measurement of any form of radiant energy. *Any* light source is giving unit illumination when its radiation measured on the far side of a luminous efficiency curve screen is of unit value.

As a matter of convenience, however, it is desirable to have certain *fixed points* or standards, by which the value of the unit may be obtained at any time without going through all the steps

requisite for its original establishment. In the case of light the fixed point presenting the greatest merit is the black body at the melting point of platinum. Its exact value is still subject to refinement of determination, but as a result of the most recent measurement [14] the following specification may be given:

As a standard fixed point in photometry the brightness of the black body at the melting point of platinum may be adopted as 58.35 *candles per square centimetre.* (F)

VI. STANDARDS OF COLOR DIFFERENCE.

In the interest of economy of labor, it is desirable to embody the results of measurements carried out under the most elaborate standard conditions, in subsidiary standards. In the case of color difference photometry the subsidiary standards take the form of illuminants of different color, or colored media, whose characteristics are reproducible and have been made the subject of measurement and specification.

In order to have such standards to meet all contingencies it would obviously be necessary to have sub-standards of an enormous number of colors, and in the course of time it is, in fact, likely that the number of color difference standards prepared for use with different illuminants will become quite large. Up to the present, however, the only standards of this sort that have been developed are for the most commonly occurring type of color difference in ordinary illuminants, namely, the black body series.

The set of such standards belonging to the photometric scale under discussion consists of a yellow and a blue solution, made up in conformity with the suggestion of Professor Fabry, of such spectral character of absorption that increasing differences of color along the black body scale are met by increased concentrations.[15] The composition of these solutions is given below. The transmissions were measured, at the time of the publication of the composition, in terms of the group of observers available at that time, and it is to be expected that the somewhat altered scale due to the greater number of observers now embodied would alter the values. As a matter of fact, however, measurements made by Crittenden and Richtmyer [6] on one of these solutions show the original calibration to hold even with the larger group of observers. This is to be ascribed to the fact that the color differ-

ences involved are much less than those of the "test colors," in whose value occurred a difference of only two per cent. Until, therefore, more refined measurements dictate a revision of the Fabry solution values, these stand as in the original publications. They are embodied in the following:

A yellow absorbing solution for use with color differences of the black body type is composed of

Cobalt ammonium sulphate	100	grams
Potassium dichromate	.733	grams
Nitric acid (1.05 gr.)	10	c.c.
Water to	1	liter

Its transmission in a thickness of one centimetre as compared with clear water is given by the formulæ,

$\log_{10} T = -0.245\, C^{0.9}$—when used over a "4 watt" lamp.

$\log_{10} T = +0.366\, C^{1.06}$ — when used over a test lamp to bring the light to "4 watt" color.

where c is concentration ..... (G)

A blue-absorbing solution for use with color differences of the black body type is composed of

Nickel ammonium sulphate	50	grams
Ammonium sulphate	10	grams
Ammonia 0.90 gr.	55	c.c.
Water to	1	liter of solution.

Dilute with water containing 10 gr. ammonium sulphate per liter.

Its transmission in a thickness of one centimetre as compared with clear water is given by the formula (H)

$\log_{10} T = -0.539\, C^{1.03}$ — when used over a "4 watt" lamp.

Details as to technic, temperature coefficients, etc., are to be found in the original publications.[15, 16]

VII. DISCUSSION.

The system of photometry which is here summarized will appear to many to be a complicated and difficult one. It is to be remembered, however, that complexity is inherent in any complete scheme for color difference photometry, both because of the nature of color vision in the individual, and because of the statistical element which enters due to the varying characteristics between individuals. Considered from this standpoint it is believed the system is in reality as simple as an adequate one can be

made. It may be emphasized that it is the *only* complete system thus far presented. It is further to be remembered that it is not the intention that the complete photometric procedure be gone through with every measurement, or in every laboratory. The ideal is to use the method for the establishment of secondary standards, by means of which all practical photometry is carried out with no color differences, leaving the fundamental color difference measurements to be made in the standardizing laboratories.

NOTES.

[1] This paper may be considered as a revision to date of portions of the communication "Proposals Relative to Definitions, Standards and Photometric Methods," presented to the Illuminating Engineering Society, May, 1915.

[2] *Philosophical Magazine*, July, September, November, December, 1912, pp. 149, 352, 744, 845, 853.

[3] The identity of the results given by the two methods *under the conditions specified, and on the employment of enough observers* to secure a significant average from the widely scattering values apt to be obtained in the juxtaposed field comparison, is a fact of experiment against which no conflicting evidence has been adduced. It has, on the other hand, been confirmed by the work of Abney and Watson, and by the extensive study of Richtmyer and Crittenden at the Bureau of Standards. It is not claimed by the writer, and never has been, that the two methods give the same results under other conditions. It was, in fact, his own researches which first showed in what manner and to what extent the two methods give different results. It is consequently quite beside the point for critics to attempt to discredit the photometric scale under discussion by blanket assertions that "*the* flicker method" gives results different from "*the* equality of brightness method." Such criticism is on a par with attempting to discredit accurate methods of linear measurement by stating that a bar of lead and a bar of platinum measured at 0° are of unequal lengths at any other temperature. The necessity for recourse to standard comparison conditions, due to the fact that response to varying conditions is different in different substances, is not peculiar to heterochromatic photometry. A red light and a blue light cannot, from the nature of vision, be equal under all conditions, and the choice of comparison conditions after a thorough consideration of the questions of utility, practicability and convenience, is entirely on a par with procedure in other departments of measuring science.

[4] There appears to be prevalent an idea that "ordinary photometry" and "the conditions of ordinary photometry" stand upon a firm basis, that they are sacrosanct, immutable, and in fact give exactly the measurements required for the proper evaluation of all light quantities. As a matter of fact there is no basis whatever for such a belief. "The conditions of ordinary photometry" are to a predominant degree accidental. They have not to this day been made the subject of definite specification, and have never, previous to the writer's researches, been studied quantitatively at all with reference to the phenomena of color perception. The only requirement for "ordinary photom-

etry" (which is photometry in which *no color difference is present*), is the use of a sufficient field brightness and size to bring the observations into the region of respectable precision of setting, when the eye is the null radiometer employed. The most common conditions (in American practice) are an illumination of about 10 metre candles (near the lower limit of the region of good photometric precision), and a field of about 5 degrees diameter. The former condition is directly traceable to the candlepower and physical dimensions of the light sources and standards in common use a decade or two ago; the latter probably is connected with the size of prism which it was originally found practicable to grind to the Lummer-Brodhun form. But neither condition is authoritatively specified or generally adhered to. As long as there is no color difference present it is unnecessary to hold to narrow conditions. In fact had the thermopile been as sensitive and as practical in form thirty years ago as now, it is not beyond the bounds of possibility that it would have been seriously advocated as a photometer, for which purpose it would have been entirely suitable, as long as no difference of color existed between the light sources under comparison. The error of using "the conditions of ordinary photometry" for colored light comparison is of the same nature, even though not as great, as is the use of a thermopile. It is inevitable that when color differences are to be compared a narrower and more exact choice of conditions must be made than sufficed formerly. It would have been entirely an accident had the "conditions of ordinary photometry" (such as they are) been identical with those dictated by a basic study of the heterochromatic problem.

It must not be overlooked by those who display concern for "ordinary photometry" that the conditions here specified for color difference photometry yield identical results to "ordinary photometry" for the only measurements for which the latter was ever suited, so that there is nothing revolutionary involved in picking conditions suited to color difference photometry. The adoption of definitely specified conditions is a step inseparable from the advance of any science. The "eye of the skilled workman" has had to yield to the pyrometer in heat measurement, and in photometry the "practiced observer" must yield to a well-considered and definitely specified photometric procedure.

[5] *Trans. Illum. Eng. Soc.*, x, No. 3, 1915.

[6] *Bull. Bur. Stds.* 14, 87, 1918.

[7] *Trans. Ill. Eng. Soc.* viii, p. 795, 1914; *Trans. Ill. Eng. Soc.*, p. 253, 1915.

[8] The method of measurement, and the method of choosing observers, as here specified, are those now in use at the Bureau of Standards.

[9] JOURNAL FRANKLIN INSTITUTE, July, 1918, p. 121.

[10] *Physical Rev.*, Nov., 1915, p. 319.

[11] Two other comparatively recent determinations of the luminous efficiency curve of the spectrum are not included for consideration because they were not made under the conditions which fix the photometric scale under discussion. The extensive investigation of Coblentz (*Bull. Bur. Standards* 303, Sept. 12, 1917, p. 168), although stated to be carried out in accordance with the procedure of the present writer, was not, in the vital particular of field brightness, which was not over one-quarter that here specified. As a conse-

quence the curve obtained by him is shifted toward the red. An experimental test of Coblentz's luminosity curve solution, based on his determination of the luminous efficiency curve, shows an error on the test colors of 4½ per cent. (JOURNAL FRANKLIN INSTITUTE, July, 1918, p. 121). The determination by Hyde, Cady and Forsythe (*Astrophysical Jour.*, Sept., 1918, p. 65) was made by the cascade method, which the writer had already shown would give the same results as the flicker method under the small field high brightness conditions specified by him. The investigators quoted, however, carried through their work under conditions of brightness and field size (the latter not specified) supposed to correspond to "the conditions of ordinary photometry," which as already pointed out, have no rational basis for use in color difference comparisons. As a consequence of their use of these conditions their curve is shifted toward the blue, as compared with the one here given. Neither Coblentz's nor Hyde's curves are coördinated with any accurately specified observing conditions nor method of choosing observers. They constitute isolated elements of photometric scales which are not only incomplete but without sound bases for adoption even if supplied with their missing parts.

[13] *Physical Rev.*, Feb., 1916, p. 161.

[14] See JOURNAL FRANKLIN INSTITUTE, Oct., 1915, p. 409.

[15] JOURNAL FRANKLIN INSTITUTE, July, 1918, p. 122.

[16] *Trans. Ill. Eng. Soc.*, p. 796, 1914; *Trans. Ill. Eng. Soc.*, p. 253, 1915.

[17] The only other color difference standards of a reproducible nature thus far published are furnished by the tungsten lamp characteristic equations of Middlekauff and Skogland (*Bull. Bureau Standards*, No. 238, p. 483, Oct., 1914). Their validity is conditioned by the uniformity of characteristics from one lamp to another, which is hard to guarantee in so complicated a product as the modern incandescent lamp. Moreover, the equations as published are based on photometric measurements carried out under conditions and with observers neither of which were the subject of study or selection, or of specification. It is understood that a revision of these equations is contemplated, based on photometric determinations made on the scale here described.

APPENDIX.

APPLICATION TO THE BLACK BODY.

THE luminous efficiency curve of the spectrum may be applied (due to the possibility of summating luminous radiations) to the calculation of the luminous characteristics of any radiation of known physical constitution and intensity. The most important case is the black body, or complete radiator. Luminous efficiency curve equations of the form above given may be combined with the Planck black body energy distribution equation and integrated to give the luminous radiation, in ergs or watts of luminous flux. From this, upon division by the constant relating the number of

watts of luminous flux to the lumen (mechanical equivalent of light), the flux, or brightness, may be immediately derived in the ordinary units of lumen and candlepower.

The form and derivation of these equations has been given by Kingsbury.[1] In re-calculating them for the new luminosity data here presented several deviations have been made from the previous procedure. As given by Kingsbury the constants are all worked out numerically, on the basis of a chosen value of the black body constant c_2, (14370). Experience in being forced to recalculate the data to several other temporarily more popular values of the constants, or to values which would make possible a real comparison of work of different observers, has suggested the desirability of stating the equations in such form that the place of occurrence of all the black body constants shows clearly. This, in turn, is but the first step in the search for a mode of expressing the luminous flux equations in which the calculations once made and tabulated will be independent of any particular choice of the black body constants. While the uncertainties in the values of these constants are becoming gratifyingly small, they still amount to a great deal when translated into terms of luminosity; and the refinements yet to be made in their determination will be important factors in their use in luminous flux equations. The desired form of the luminous flux equations, into which the latest and best values of the constants can be introduced at any time, is furnished by taking advantage of the fact that the two variables, *shape of the emission curve* (determined by $\frac{c_2}{T}$) and *luminous efficiency* (ratio of the light-evaluated to the total energy), are connected by definite values which may be calculated without assuming definite figures for the black body constants. Accordingly the data herewith plotted are values of $\frac{L}{R}$ (where L is the light-evaluated, R the total radiant energy), against $\frac{c_2}{T}$.

Expressed in this new form the flux equation as developed by Kingsbury becomes

$$\frac{L}{R} = \left(\frac{c_2}{T}\right)^4 \times .01922 \left[\Sigma\, p \frac{\frac{1}{\sqrt{n}}\left(\frac{n+3}{n}\right)^n + \frac{7}{2}}{\frac{4}{\lambda_m}\left(\frac{1}{n\lambda_m}\frac{c_2}{T}+1\right)^{n+4}}\right] \qquad (1)$$

Upon introducing the constants of the luminous efficiency curve equation as developed in the body of the paper this equation becomes

$$\frac{L}{R}=\left(\frac{c_2}{T}\right)^4\left[\frac{.28730}{\left(.008993\frac{c_2}{T}+1\right)^{204}}+\frac{.0070326}{\left(.001282\frac{c_2}{T}+1\right)^{1304}}+\frac{.022581}{\left(.01064\frac{c_2}{T}+1\right)^{204}}\right] \tag{2}$$

TABLE I.

Black Body Luminous Characteristics.

$\frac{C_2}{T}$	$\frac{L}{R}$	$Log_{10}\frac{L}{R}$	λ_e
1	.0514	$\bar{2}$.71096	.546μ
2	.1296	$\bar{1}$.11261	.5515
3	.1085	$\bar{1}$.03551	.5575
4	.05755	$\bar{2}$.76102	.5635
5	.02416	$\bar{2}$.38303	.569
6	.008778	$\bar{3}$.94340	.5745
7	.002864	$\bar{3}$.45697	.5795
8	.0008768	$\bar{4}$.94290	.5845
9	.0002479	$\bar{4}$.39435	.5895
10	.00007198	$\bar{5}$.85721	.5945
11	.00001994	$\bar{5}$.29937	.5995
12	.000005217	$\bar{6}$.71740	.604

Calculated values, using this equation are listed in Table I and plotted (in terms of the logarithm of $\frac{L}{R}$), in Fig. 1.

In order to arrive at definite values of luminous flux it is, of course, necessary to choose and introduce definite values for the black body constants. Thus to obtain L, the luminous flux in watts, we use the relation

$$L=\left(\frac{L}{R}\right)\times\sigma\ T^4 \tag{3}$$

To obtain the normal flux L_0, we use the equation

$$L_0=\left(\frac{L}{R}\right)\times\frac{\sigma\ T^4}{\pi} \tag{4}$$

To transform these results to lumens and candlepower we divide by m, the watts of luminous flux in the lumen, thus

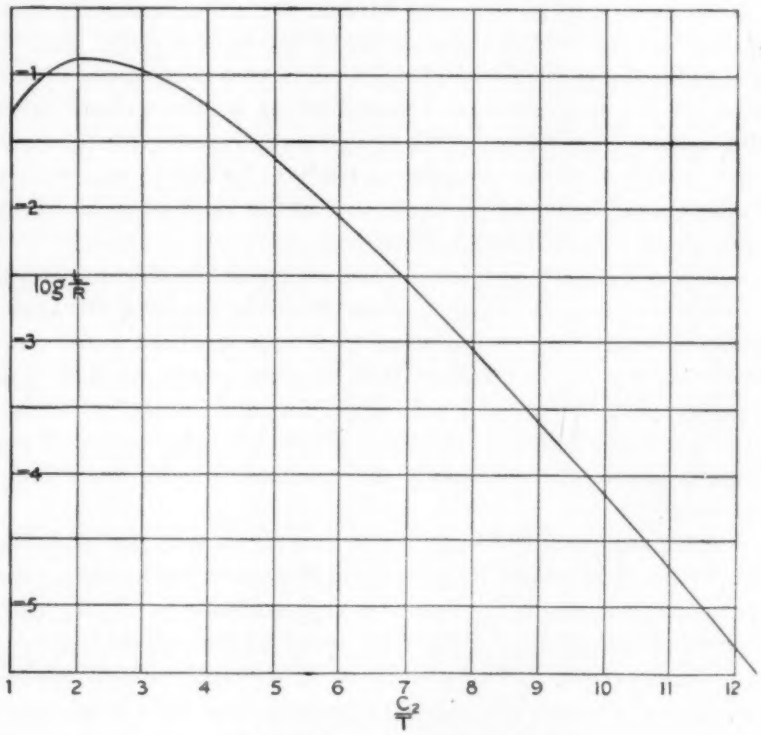
$$F=\left(\frac{L}{R}\right)\times\frac{\sigma\ T^4}{m} \tag{5}$$

$$F_0=b=\left(\frac{L}{R}\right)\times\frac{\sigma\ T^4}{\pi m} \tag{6}$$

Some illustrations of the use of these equations are of interest. Two characteristic ones are furnished by the luminous properties of the black body at the melting points of gold and platinum respectively:

Assuming Millikan's values for the black body constants, we have for gold, with its well-established melting point of 1336° K.,

FIG. 1.



Luminous efficiency of the black body.

the value $\frac{14312}{1336}$ = 10.7125 for $\frac{C_2}{T}$. Using this in (2) we obtain for $\frac{L}{R}$ the figure .000000002172. From (4), taking 5.72×10^{-12} for σ we obtain for L_0 the value .0001659. Dividing this by .00156, the value chosen in the body of the paper for m, we finally get for the brightness of the black body at this temperature,—

0.1062 candles per square centimetre.

The latest determination of this quantity is that of Holst

and Visser.[2] Their value is 0.1071. Details of their photometric method are not at present available, so that the accuracy with which it is represented by the luminous efficiency curve here chosen is problematical. Furthermore, it is to be noted that the calculated brightness varies with enormous rapidity [3] with the choice of c_2. On the whole, therefore, the agreement of calculated and observed values to within one per cent. is excellent.

In the case of platinum, if we take the same black body constants, together with the latest value for the melting point, namely, 2037° K., the result for the brightness is 55.9 candles per square centimetre. Experimental determinations by the writer [4] gave this quantity as 58.35. This leaves a discrepancy of four per cent., which, however, is quite as likely to be due to uncertainty in the melting point of platinum, and in the value of c_2, as in the photometric method and calculations.

It is evident from these calculations, applied in the one case to a region where photometric observation is reaching its lower limit of feasibility, in the other to a region where exact temperatures are still in question, that the photometric methods and equations are in very practical shape for use. In the form they are here presented they will be available for calculations of the highest precision immediately the constants of the black body are fixed.

A second quantity of interest in connection with the luminous properties of the black body is the *equivalent wave-length* or the wave-length at which the rate of energy emission is varying with change of temperature at the same speed as the rate of luminous emission changes. (The equivalent wave-length, which applies to *one* temperature, is to be distinguished from the *Crova wave-length,* which is the wave-length to be used in comparing emissions due to *two* different temperatures. To a close approximation the Crova wave-length is the mean of the equivalent wave-lengths.)

Expressing the equations derived by Kingsbury [1] for the equivalent wave-length in terms of the more convenient variables $\frac{C_2}{T}$ and $\frac{L}{K}$ we get

$$\lambda_e = \frac{\Sigma\, p \dfrac{\frac{1}{\sqrt{n}}\left(\frac{n+3}{n}\right)^{n+\frac{7}{2}}}{\lambda_m^{4}\left(\frac{1}{n\lambda_m}\frac{C_2}{T}+1\right)^{n+1}}}{\Sigma\, p \dfrac{\frac{1}{\sqrt{n}}\left(\frac{n+3}{n}\right)^{n+\frac{7}{2}}\left(\frac{n+4}{n}\right)}{\lambda_m^{5}\left(\frac{1}{n\lambda_m}\frac{C_2}{T}+1\right)^{n+5}}} = \frac{\frac{L}{R}}{\left(\frac{C_2}{T}\right)^{4}\times .01922 \times \left[\Sigma\, p \dfrac{\frac{1}{\sqrt{n}}\left(\frac{n+3}{n}\right)^{n+\frac{7}{2}}\left(\frac{n+4}{n}\right)}{\lambda_m^{5}\left(\frac{1}{n\lambda_m}\frac{C_2}{T}+1\right)^{n+5}}+\right]} \tag{7}$$

Introducing the numerical values derived from the luminosity curve equation, this becomes

$$\lambda_e = \frac{\frac{L}{R}}{\left(\frac{C_2}{T}\right)^{4}\times\left[\frac{.52708}{\left(.008993\frac{C_2}{T}+1\right)^{205}}+\frac{.011757}{\left(.001282\frac{C_2}{T}+1\right)^{1305}}+\frac{.049244}{\left(.01064\frac{C_2}{T}+1\right)^{205}}\right]} \tag{8}$$

Values calculated from (8) are given in Table I, and are plotted in Fig. 2.

The plotted values of λ_e lie on a smooth curve, which is represented with considerable accuracy by an equation of the form

$$\lambda e = a + b\left(\frac{C_2}{T}\right) + c\left(\frac{C_2}{T}\right)^2 \tag{9}$$

Solving for the constants we find the following numerical equation to represent the curve well,

$$\lambda e = .5402 + .0062\left(\frac{C_2}{T}\right) - .000074\left(\frac{C_2}{T}\right)^2 \tag{10}$$

It has been pointed out by Foote [5] that an equation of this form may be made the basis of an empirical luminous flux equation of comparatively simple form for numerical calculation. In order to form such an equation in terms of $\frac{C}{T}$ and $\frac{L}{R}$ we note

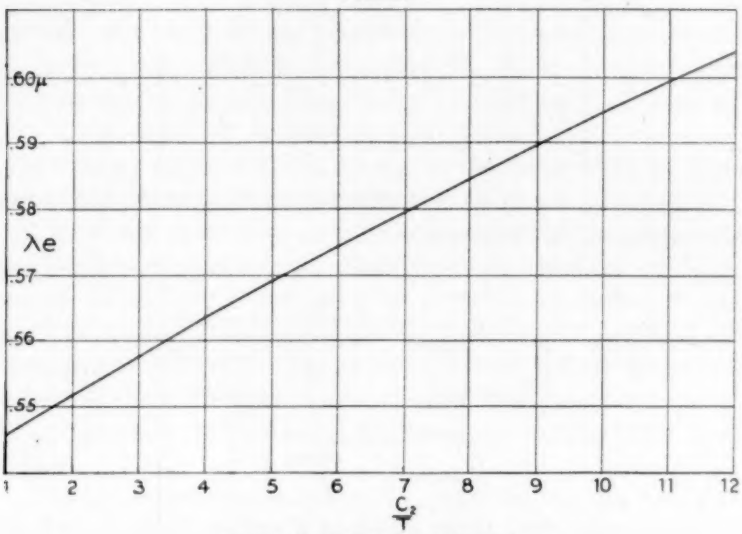
that if the luminous radiation is considered as monochromatic we may represent it by the expression

$$L = c_1' \lambda^{-5} e^{-\frac{c_2}{\lambda T}} \tag{11}$$

and $\frac{L}{R}$ by the expression

$$\frac{L}{R} = c_1' \lambda^{-5} e^{-\frac{c_2}{\lambda T}} \sigma' \left(\frac{c_2}{T}\right)^4 \tag{12}$$

FIG. 2.



Black body equivalent wave-lengths.

From this is immediately derived the relation

$$\frac{d \log \frac{L}{R}}{d\left(\frac{c_2}{T}\right)} = -\frac{1}{\lambda} + \frac{4}{\left(\frac{c_2}{T}\right)} \tag{13}$$

If now we substitute the complete expression for λ_e from (10) we get

$$\frac{d \log \frac{L}{R}}{d\left(\frac{c_2}{T}\right)} = -\frac{1}{a + b\left(\frac{c_2}{T}\right) + c\left(\frac{c_2}{T}\right)^2} + \frac{4}{\left(\frac{c_2}{T}\right)} \tag{14}$$

Integrating this we get

$$\log \frac{L}{R} = \frac{1}{\sqrt{b^2 - 4ac}} \log \left(\frac{\frac{c_2}{T} + \frac{b + \sqrt{b^2 - 4ac}}{2c}}{\frac{c_2}{T} + \frac{b - \sqrt{b^2 - 4ac}}{2c}} \right)^{\frac{1}{\sqrt{b^2 - 4ac}}} + 4 \log \left(\frac{C_2}{T} \right) + A \qquad (15)$$

Solving for numerical values this becomes

$$\log \frac{L}{R} = 71.005 \log \left(\frac{\frac{c_2}{T} - 137.16}{\frac{c_2}{T} + 53.378} \right) + 4 \log \frac{c_2}{T} - 19.6100 \qquad (16)$$

This expression gives results of about one per cent. accuracy, and is considerably quicker than (2) to work with. Its derivation presupposes the true values known from the direct procedure.

NOTES TO APPENDIX.

[1] *Physical Review*, Feb., 1916, p. 161.

[2] Holst and Visser, K. Akad, Amsterdam, 1918.

[3] In the region of the gold point the calculated luminous efficiency changes almost exactly 1 per cent. for each unit in the fourth place of the assumed value of c_2. The present uncertainty in the value of c_2 is four or five units in this place (14300 to 14350).

This rapid variation of calculated luminous efficiency with c_2 suggests that a highly sensitive method of determining this constant lies in the experimental determination of $\frac{L}{R}$ for the black body at the well established gold point. L could be established photometrically by comparison with a light source of the same color as the black body at this temperature, but of sufficient intensity to furnish measurable radiation through a luminous efficiency curve filter of accurately known transmission. Such a source is at hand in the "4 watt" carbon lamp in conjunction with a 90 per cent. concentration "Fabry" yellow solution.

[4] JOURNAL FRANKLIN INSTITUTE, July, 1918, p. 122.

[5] *Bull. Bureau Standards*, 270, Mar., 1916.

Salving Trench Hosepipe. (*Journal of Industrial and Engineering Chemistry*, vol. xi, No. 7, p. 690, July 1, 1919.)—An interesting side line of war salvage is being carried on at Hayes, Middlesex, England, where some hundreds of miles of trench hosepipe are being disintegrated and the various products recovered for sale. This type of hose contains a large amount of iron wire and canvas impregnated with a small proportion of rubber. A special machine has been designed for treating the hose, and the stripped wire is stated to be worth about $60 a ton at present prices. The rubber is being reclaimed and the canvas ultimately finds an application as cellulose. The work is being done on a part of the premises of a detinning works, where considerable quantities of scrap tin are now being treated by the electrolytic process with satisfactory results. Metal containing as much as 99.8 per cent. of tin is being obtained from the scrap.

Zirconium Steels. J. GARCON. (*Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. 131, No. 1, p. 148, January–February, 1919.)—Zirconium is not found in nature in the metallic state. It occurs in Norway, Ceylon and Brazil, and nearly everywhere in the form of orthosilicate. Zircon or hyacinth contains two-thirds oxide of zirconium or zirconia and a third of the silicate with some impurities. Its density is very high, reaching 4.7. Another richer mineral is badelyte, of which quite copious deposits are found in Brazil and also in Ceylon. This is a natural zirconia whose content of ZrO_2 varies from 69 to 94 per cent. Several methods are followed to obtain more or less pure oxide. Zirconia is employed, in view of its high temperature of fusion, in the manufacture of crucibles and for the linings of metallurgical furnaces. Zirconium enters also in the composition of Nernst-lamp filaments, in the leads of the Bleriot-lamp, and as a component of a special glass which may be substituted for quartz-glass.

An important application of zirconium is found in the manufacture of alloy steels. Tests at the Ford laboratory on armor-piercing-bullet-shields have shown that nickel-zirconium steel plates 10 mm. in thickness have a resistance to penetration equivalent to nickel-chrome steel 16 mm. thick and nickel-molybdum steel 13 mm. thick. The zirconium is added in the form of a 30 per cent. ferro-alloy. This alloy is produced by reducing the mineral in the electric furnace with aluminum. It is essential that the alloy contain not more than 5 per cent. of aluminum, otherwise the presence of the aluminum diminishes the strength of the steel.

DEVELOPMENT OF AN AIRPLANE SHOCK RECORDER.*

BY

A. F. ZAHM, Ph.D.

Bureau of Construction and Repair, Navy Department.

To meet the current needs of the airplane designing staff of the U. S. Navy, an airplane accelerometer was developed for measuring the sudden loads and shocks encountered in flying, and landing. An elaborate instrument of precision was not called for, but rather a device whose records could be obtained easily and read directly. For the scale drawings and early tests of the design here described the writer is indebted to his assistant, Mr. L. Crook, who first calibrated the accelerometer, then used it on a flying boat to measure landing shocks.

Fig. 1 pictures the instrument in course of development. It consists of many vertical styluses, or pointed rods, supported individually by springs and recording on a single chronograph drum over which passes a continuous sheet of sensitized paper. For measuring upward accelerations the rods, which are all of the same mass, are pressed upward against stops by springs of graded intensity, while their pointed lower ends, or needles, are held within a few thousandths of an inch of the chronograph drum. When acceleration occurs a certain number of styluses begin to record instantly, as the intensity of the force overcomes in succession stronger and stronger springs.

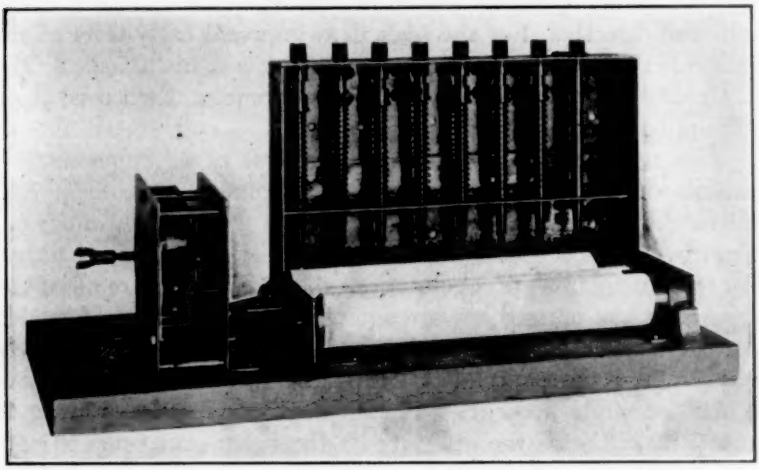
When preparing the instrument for any proposed measurement one sets the springs so as to meet any probable accelerations that will have to be recorded. By means of the sliding sleeves shown in the photograph the force of the springs can be adjusted so as to equal any multiple of the weight of a rod. To this end one applies in succession to each stylus, by contact with a weighing scales, forces which are multiples or fractions of the whole fixed weight of the rod plus half the weight of the spring, while the springs are adjusted so as barely to support the rod against the stop. A single rod of brass weighs about 1¾ ounces, being $^9/_{32}$ inch diameter by 5 inches long.

---

* Communicated by the Author.

To prevent the needle from scratching or puncturing the paper it is cushioned against a spiral spring inside the holder, or vertical rod, within which it can otherwise slide freely. The needle at its middle is provided with a shoulder abutting against the upper end of the small holding and adjusting screw. This screw can, by rotating, raise or lower the setting of the needle, and is securely fixed in place by the jam nut shown at the bottom of the rod. The needle is of brass or German silver, and makes a clear, fine mark on the chemically treated paper when the pressure is three per cent., or more, of the weight of the holder. One

FIG. 1.



per cent. of the weight would be sufficient pressure with styluses fifty per cent. longer and thicker, for a test has shown that .05 ounce pressure of the needle causes a clear trace.

In the position and adjustment shown, the present instrument records only upward accelerations, but by inversion can, without further adjustment, record downward accelerations, provided account be taken of the reversed direction of gravity. Thus, if when upright, the stylus exerts on the stop a pressure nw, inverted it exerts $(n+2)\ w$; and hence records accelerations ng, $(n+2)g$, w being its weight. Without inversion the instrument also records negative accelerations if the styluses be pressed downward against their stops. Also in its upright position the

instrument records both positive and negative aceclerations when the springs are set so that some styluses are pressed upward and others downward.

The special stylus shown on the right of the photograph is provided at its upper and lower ends with thin cantilever springs which prevent it from rubbing against the guide plates of the containing box, and at the same time hold the rod upward against its stop in the manner described for the spiral springs. An instrument with such cantilever, or anti-friction, springs could be used to measure horizontal as well as vertical accelerations.

In the form here shown the instrument is provided with six feet of paper driven by an alarm clock at the rate of two inches per second for such accelerations as are found in aeroplane experiments. This rapidity is essential in order to separate and clearly disclose landing shocks and structure vibrations; for it is usually the short hammer-blow shocks of a few hundredths of a second duration which most stress the under parts of an airplane in alighting on land or water.

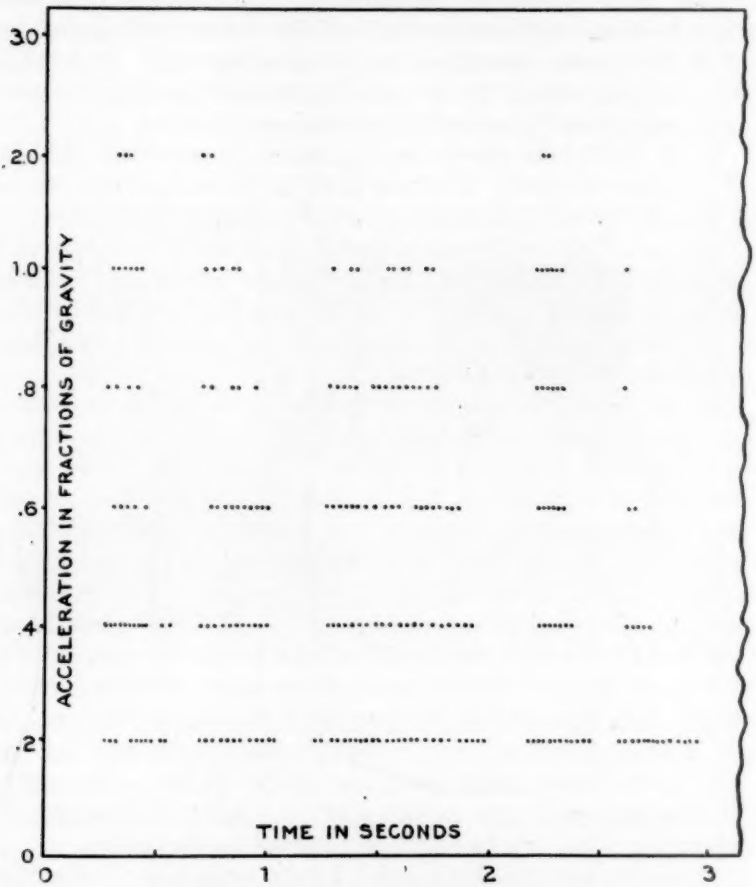
In action the instrument appears to be fairly instantaneous and free from the oscillations found in a spring accelerometer whose recorder has a considerable displacement. Thus each needle records without interruption a definite continuous acceleration beyond a certain intensity, but instantly ceases recording when the acceleration falls below this amount. It can also simultaneously record long and short accelerations. For example, engine tremors superposed upon an air swell cause a needle to make a dotted trace; the length of the trace representing the duration of the swell beyond a certain intensity, and the distance between dots representing the period of the engine tremor. In fact, a known engine speed serves to standardize that of the paper, and a known paper speed that of the engine. The aggregate tracings of all the needles form a shaded diagram whose contour is a wavy line like that of a spring accelerometer.

An example of typical records taken on a seaplane is presented in Fig. 2 of this report. The farther stylus, which has its restraining spring adjusted to record upward accelerations of twice gravity, has made a few instantaneous traces separated by long blanks; the one set for two-tenths of gravity has made long traces with short blanks. Both records are dotted, showing engine tremors. Feeble accelerations were expected, otherwise a more

suitable setting of the springs would have been made. They should have been graded to tenths in the region of two gravities.

Fig. 3 gives an acceleration record of an approximately simple harmonic motion, somewhat damped, made with the instrument

FIG. 2.

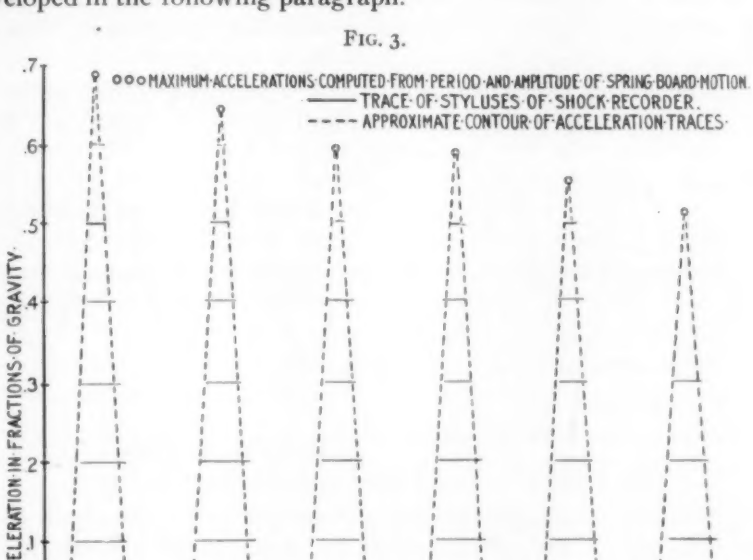


Landing accelerations on pontoon of Curtis JN—4E.

screwed to the end of a vertically vibrating spring-board clamped in a firm vise on a not very firm table, and with its styluses set only for positive accelerations. Plotted on the same diagram, as a line of small circles, are the simultaneous maximum accelerations of a needle inserted in the end of the spring-board and play-

ing on a sheet of smoked paper moving steadily past it. The line of circles is a "damped" harmonic with a perceptible "overtone," and matches the damped acceleration trace taken simultaneously, all recorders being equally distant from the face of the vise. The actual tracing of the spring-board tip is given in Fig. 4, and the method of computing from this the maximum accelerations, which are indicated by the circles in Fig. 3, is developed in the following paragraph.

FIG. 3.



Calibration diagram for shock recorder.

Without rigorous precision the general equation to the vertical motion of the spring-board tracing point may be written

$$\ddot{s} + a\ddot{s}^2 + b\dot{s} + cs = o$$

in which s is the displacement, at any time t, from the point of rest under gravity, and $a\ddot{s}^2$, $b\dot{s}$, are retardations due to the air resistance and internal friction of the vibrating system. The maximum acceleration for any one vibration occurs when $\dot{s} = o$, and may be written from the equation

$$\ddot{s} + cs = o.$$

It is

$$\ddot{s}_1 = -cs_1$$

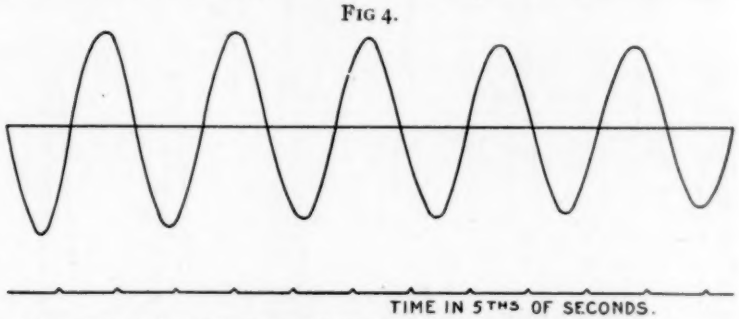
in which s_1 is the momentary amplitude. Since the damping is small, $\ddot{s}_1$ can also, without material error, be written in the more familiar form

$$\ddot{s}_1 = -4\pi^2 n^2 s,$$

when n is the frequency. Now, since $\ddot{s}_1$ is approximately recorded by the acceleration styluses, and $\ddot{s}_1$, n, are found in the record of the vibration stylus, the one record can be checked with the other. This method was used in computing from the trace of the spring-board's motion, the accelerations indicated by circles in Fig. 3.

The acceleration records are fairly trustworthy as far as they go, but lack continuity, like the markings on a yardstick. To

FIG 4.



Trace of tip of vibrating spring board used in calibrating accelerometer.

disclose accurately the maximum acceleration in any shock the adjustment of the springs must be close-graded. Thus, if a maximum acceleration of twice gravity be recorded by styluses graded to tenths of gravity, the greatest possible error is presumably one-tenth of gravity, or five per cent. of the quantity recorded, while the probable error is two and one-half per cent. Still closer estimates can be made by sketching in the contour of the traces. The free play of the styluses between their stops must, of course, be kept small.

Closer agreement between the two sets of superposed values in Fig. 3 would ensue if the clock ran uniformly; if the paper were uniformly thick, instead of being spliced; if the needle points were set 0.004 inch from the paper, instead of 0.012 inch; and if the styluses were given less play between their stops. These adjustments would be made in refining the instrument. But, even so, the records would not everywhere accurately disclose the acceleration, unless made with numerous styluses in close-graded

adjustment. At one point, such as the third crest in Fig. 3, the record might be a mere dot, and hence indicate the acceleration truly; at another it might be a dash, leaving the true crest to be extrapolated. Numerous and close-graded styluses can, of course, be provided without much increase of cost or weight, if found desirable for special investigations.

For the immediate measurements in view it was thought unnecessary minutely to calibrate the shock recorder to a close-grade scale by experiment. Continuous recording instruments are in the market, such as the R A F photographic accelerometer, or in development, such as the Sperry mechanically recording accelerometer, and these may be had in time. The present instrument has served a passing need, and may prove useful for disclosing hammer-blow shocks too sudden to be faithfully recorded by accelerometers of another type.

For a comprehensive field laboratory study of the accelerations throughout an airplane it may be well to measure simultaneously the shocks in the undercarriage, the body and the wings. This can be done either by placing individual recorders in those parts, and synchronizing them, or by placing shock receivers there and recording on a central chronograph. The present instrument, or a simpler one consisting of plane bar springs, could be used as a contact maker in various parts of an airplane to operate recording magnets at a central drum. Such an apparatus can easily be arranged, and may be expected to record with about the promptness of a ballistic or an astronomical chronograph.

For instantly indicating to the pilot the comparative stressing of his machine a number of simple bar-spring contact makers of graded strength can be coupled to a row of tiny electric lamps on the instrument board. These would brighten successively, and indicate by their various colors, positions, or markings, the degree of stress put upon his craft. A tentative instrument of this kind has been tried incidentally to the present study. Such cantilever styluses, or contact makers, have the simplicity and compactness of a row of piano keys, but are not preferred to the endwise-moving styluses because they are more affected by angular accelerations about their centres of gravity, or points thereabout, than are the rods used in the present instrument. Obviously the contact points could be used with a smaller gap than have the needles recording on paper.

Without its base the present instrument, whose case measures 9 inches by 6 inches by 1.5 inches, weighs eight pounds, being made almost wholly of brass. By using aluminum, where practicable, the whole weight can be reduced to about two pounds. In this style the clock would form part of the case, and the whole could be screwed to the instrument board of an airplane.

Lignum-Vitæ, the Vital Wood. S. J. RECORD. (*Scientific American Supplement*, vol. lxxxviii, No. 2270, p. 4, July 5, 1919.)—The propeller shaft of every battleship, every destroyer, every transport, in fact, every large steamship, revolves in a wooden bearing at the stern end. Of all the thousands of woods in the world, true lignum-vitæ, a native of the West Indies and certain other parts of tropical America, is the only one that has been found equal to this exacting service. The peculiar properties which so well fit lignum-vitæ for the purpose are due to the arrangement of the fibres and the resin-content of the sap cells. The fibres never run straight up and down the log, but weave back and forth in a serpentine manner that cross and criss-cross like the corded fabric of an automobile tire. The result is a material of extreme tenacity and toughness. When the sap cells cease to function, their every nook and cranny become filled with a resin which is about a third heavier than water. The result is a material which weighs about 80 pounds per cubic foot.

Stern bearings provide the most important use for lignum-vitæ but by no means the only one. Formerly it was in great demand for bowling balls, but now only one ball in ten is made of wood. A large quantity of low-grade logs, known as "cutting-up" wood, is consumed in the manufacture of rollers for furniture casters. Small round sticks make excellent mallets and fill a large demand, especially in England. Another important use is for sheaves of pulleys, and they have been known to last in constant use for seventy years. Another nautical application is for "dead-eyes," a small flattish block with a grooved rim to fit in the bight of a rope or encircled by an iron band, pierced with three holes to receive a lanyard, and used to extend the shrouds and stays. Among the miscellaneous uses may be mentioned stencil and chisel blocks, watchmakers' blocks, mortars and pestles, dowels, golf-club heads, wooden cogs, water wheels and block guides for band saws. In building the Panama Canal, the true lignum-vitae made the most serviceable railroad ties that could be obtained. Between 150 and 200 tons of genuine lignum-vitae are used every year in New York for fuel in grate fires. The very dense nature of the wood, together with the heavy resin content, produces a fuel with intense glowing heat and good lasting qualities. This provides one outlet for defective and crooked logs which are found in every shipment.

PITCH POCKETS AND THEIR RELATION TO THE INSPECTION OF AIRPLANE PARTS.*

BY

J. R. WATKINS.

Assistant Engineer in Forest Products, Forest Products Laboratory, U. S. Forest Service, Madison, Wisconsin.
Member of the Institute.

In the inspection of important wood parts for airplanes it is essential to know as accurately as possible the effect of any defect on strength. In the early days of airplane manufacture the builder could go to almost any length in securing wood entirely free from knots, imperfections of grain, pitch pockets, or any blemish or defect; in other words, absolute perfection could be insisted upon. When airplanes began to be manufactured on a large scale for war purposes and we began to look forward to a commercial development of the airplane it became impossible to insist on this absolute perfection. Consequently, accurate knowledge of the effect of all sorts of defects is becoming increasingly essential.

Among the defects found in the coniferous species used for airplanes, such as spruce and Douglas fir, a common one is pitch pockets. This article is a brief résumé of theories advanced to account for the presence of pitch pockets and the results of tests to determine the effect of pitch pockets on the strength of airplane wing beams. The tests were made at the Forest Products Laboratory of the United States Forest Service, in coöperation with the Air Service of the Army and the Bureau of Construction and Repair of the Navy.

ORIGIN AND OCCURRENCE OF RESIN POCKETS.

Resin pockets are hollow recesses in the wood of conifers, which are more or less completely filled with resin.

A theory advanced about 75 years ago is that they are caused by the dissolving of wood parenchyma clusters in such a manner that wood tissues are transformed into resin.

Another theory [1] contradicts the first with the following statements: "*First,* the pitch pockets in the very newest annual

* Communicated by the Director of the Forest Products Laboratory.

[1] H. Mayr in "Das Harz der Nadelhölzer, etc.," pp. 36–40.

ring are lined with parenchyma just the same as those in wood over a hundred years old; there are no pitch pockets whose parenchymal lining is entirely dissolved away. *Second*, the pitch pockets are formed at a time and in a surrounding structure in which all processes are engaged in the direct opposite of dissolution; that is, in cell formation and reproduction; namely, in the cambium and during the cambial activity. The pitch pockets are filled with resin from the very first moment of their origin, even before the isolation parenchyma is fully formed. *Third*, fir (*Abies*) and arbor vitæ have abnormal parenchyma, like the spruce, but in neither of the first named species does one ever find a pitch pocket, since pitch pockets stand in a causal relation with resin ducts, which latter, as is well known, are absent in fir (*Abies*) and arbor vitæ.

"There remains, therefore, for the origin of pitch pockets, only the one explanation, that at the time of the cambial activity, resin is squeezed from the horizontal canals into cambial layers, which having been split thereby, are entirely separated for a certain extent of their surface by the outpouring of resin. This resin, gushing out into the soft, thin walled and as yet uncompleted layers, kills the neighboring cells, which then collapse. There then begins on the part of the more distant parenchymal cells, an inner overgrowth by means of the formation of proud-wood parenchyma, which isolates the resin which has poured out and in this way renders it harmless. The resin is squeezed into the cambial layers with such force that at this point a considerable expansion of the very thick bark results.

"It is difficult to determine what causes the pathological exudation of resin from the horizontal canals into the growing cambial layer. It is well known that, on account of the turgidity of the sapwood layers, the resin in the resin ducts is under very high pressure. The only way in which resin is made use of in the case of the spruces and pines is by pressure exerted upon the resin by the juicy sapwood. This is the only force which is able to overcome the resistance of the exceptionally fine capillaries (resin ducts). Wherever the tension due to the changing turgidity of the structure changes most rapidly, one finds the most pitch pockets.

"Because of this fact pitch pockets are most frequently found

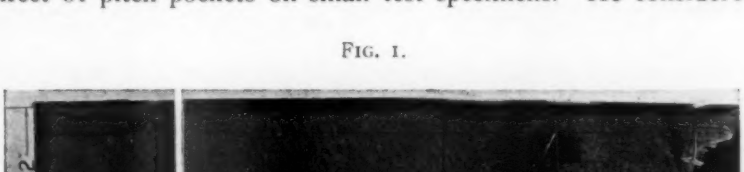
in the vicinity of branches from the main trunk. On account of these branches the ascending water current, which is deflected from the main course at an angle, is dammed up. Those trees which stand alone, and are therefore subjected to all extremes of temperature and humidity, are noticeably richer in pitch pockets than trees which have grown up surrounded by the forest."

Another theory is that the tree is wounded by means of some external force. The resin then flows to the wound, where it assists in protecting the surface against drying out until it can be healed by an overgrowth of proudwood.

TESTS OF THE EFFECT OF PITCH POCKETS ON THE STRENGTH OF AIRPLANE WING BEAMS.

One investigator made a considerable number of tests of the effect of pitch pockets on small test specimens. He considered

FIG. 1.



Length 8 inches, width 1½ inches, depth ¼ inch. Showing pitch pockets and resin flecks in a piece of white pine.

that pitch pockets were evidence of a diseased condition of the wood. He also recommended that inspectors reject wood with very large pockets, and in the case of wood with pockets that are smaller but exceed 1 by ⅛ inch in dimensions special attention be directed to the grain, and all resin-pocketed wood showing slight general waviness or slight general obliquity of grain be rejected. He states that pitch pockets of 1 by ⅛ inch in dimension are not in themselves a cause of weakness and for this and other reasons the position of the visible pockets of this size on a finished airplane part is not of paramount importance. These tests were made in England on "silver spruce," presumably Sitka spruce.

The theory that pitch pockets are merely evidence of a diseased

condition seems untenable. In the many thousands of tests of various coniferous species made at the Forest Products Laboratory there has been no evidence that the presence of pitch pockets is indicative of a disease which weakens the wood.

During the early part of the war the rejection of wing beams and other important parts because of the presence of pitch pockets was quite large.

There are about 20 inspections of each beam and strut from the time it enters the mill until it goes into the plane and each inspection eliminates a fair percentage of the material. Following is a table of data compiled during one month by an inspector in a plant making DH-4 wing beams:

Number and Percentages of DH-4 Wing Beams Rejected for Various Causes at Final Inspection.

Cause for Rejection.	Spiral Grain	Diagonal Grain	Dip	Knot	Pitch Pocket	Warp	Check	Damage	Wind Break	Glue Failure	Dote
Number rejected....	305	16	97	79	138	65	218	59	59	17	7
Per cent. of total number rejected....	28.8	1.5	9.2	7.6	13.0	6.2	20.0	5.6	5.6	1.7	0.8
Per cent. of total number inspected...	4.4	0.2	1.4	1.1	2.0	0.9	3.1	0.8	0.8	0.2	0.1

Total Beams Inspected = 7016
Total Beams Rejected = 1060
Per cent. Rejected = 15.1

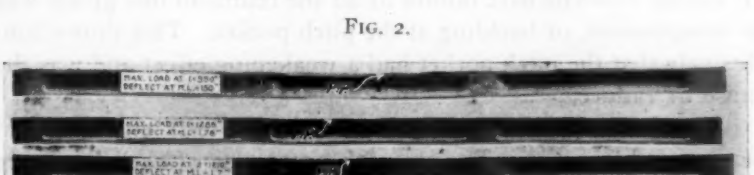
This inspection was of finished beams and the table does not indicate the percentage rejected before they had reached this stage.

At the suggestion and with the coöperation of Captain O. P. M. Goss of the Spruce Production Division, a series of tests to determine the effect of pitch pockets of various sizes located in different parts of Douglas fir wing beams was undertaken at the Forest Products Laboratory of the United States Forest Service, Madison, Wisconsin. Sixty pairs of Douglas fir beam blanks 2 by 4 inches by 7 feet were selected by Captain Goss at the mills. It was the intention in selecting these that one beam of each pair should be entirely free from pitch pockets and that the other should have pitch pockets in certain parts of the beam. Blanks giving

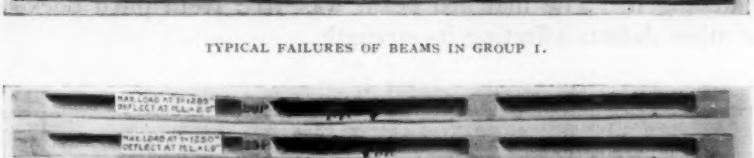
promise of filling these qualifications were selected and shipped to the laboratory. The two beams of each pair were taken from the same height in the tree and at the same distance from the pith, that is, from the same annual rings of growth.

On arrival at the laboratory this material was carefully kiln dried to about 10 per cent. moisture. The blanks were then routed to the I-beam form shown in Fig. 2 for test in bending over a span of 6 feet with loads at the third points of the span.

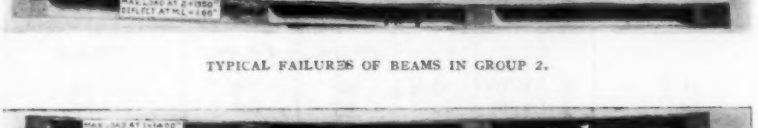
FIG. 2.



TYPICAL FAILURES OF BEAMS IN GROUP 1.



TYPICAL FAILURES OF BEAMS IN GROUP 2.



TYPICAL FAILURES OF BEAMS IN GROUP 3.

Pitch pockets and their influence on the mechanical properties of Douglas fir airplane wing beams. Showing typical failures of tested beams with pitch pockets in various parts.

These beams were 2¾ inches high by 1⅝ inches wide with ⅜-inch webs and flanges. A length of 3 inches was left unrouted at each support and each load point. Pitch pockets in some of the blanks were eliminated in the routing.

Beams were divided into groups 1, 2, and 3.

Group 1 included beams having pitch pockets in the compression flange and between load points. Group 2 included beams

having pitch pockets in the tension flange. Group 3 included beams having pitch pockets in the web and between support and load point. Each beam containing pitch pockets had a mate free from pitch pockets selected as previously described and tested in exactly the same manner.

Fig. 2 shows typical failures of beams of each group. The numerals "1" and "2" indicate the order in which failures occurred.

Group 1.—The first failure of all the beams in this group was by compression, or buckling at the pitch pocket. This shows conclusively that the pitch pocket had a weakening effect and was the cause of failure.

The following table gives the results of tests on individual beams of this group. The strength properties of each beam are given as a percentage of the same strength property of the beam matching it. The matched beam was free from pitch pockets or other defects affecting its strength.

TABLE I.

Beam No.	Dimension of Pitch Pocket in inches			Modulus of Rupture	Modulus of Elasticity	Work to Maximum Load
	L	*W*	*D*			
				Per cent.	*Per cent.*	*Per cent.*
31 P	2	1/16	3/4	99	85	93
22 P	3	1/8	....	93	106.5	87
33 P	3	1/16	....	98	101.0	100
37 P	3	1/8	1 1/4	95	98.5	94
41 P	3	1/16	....	93	97.5	91
17 P	5	1/8	1 1/8	77	99.5	55
35 P	5	1/8	....	88	88	86
29 P	6	1/8	1 1/4	76	81	67

L = length of pitch pocket.
W = width of pitch pocket as seen on face of beam.
D = depth of pitch pocket, *i. e.*, distance it extends into beam.

All beams in this series had the annual growth rings horizontal in the beam, consequently, *W* is the radial and *D* the tangential (to the annual rings) dimension of the pitch pocket.

Beams from which the pitch pockets were eliminated in routing were also tested and compared to other clear beams matched to them in the same way as clear beams were matched to beams

with pitch pockets. There were 80 clear beams matched in pairs in this manner. Data from these tests are of assistance in interpreting the results given in Table I. These data show that "matched" pieces differ from each other even when both are free from defects.

	Modulus of Rupture	Modulus of Elasticity	Work to Maximum Load
Average ratio of strength property of a clear beam to that of another clear beam matched to it	.990	.988	.996
Probable deviation of individual ratio from average	.044	.046	.111

The figures on "probable deviation" indicate that with material selected and matched, as in the present instance, a piece which is clear of defects will in one case out of four be expected to be no more than 94.6 per cent. as strong in modulus of rupture as its mate (also free from defects). The corresponding figures for the other properties are modulus of elasticity 94.2 per cent., work to maximum load 88.5 per cent.

From this it is seen that two of the four pieces with 3-inch pitch pockets fall below their mates by an amount which would be expected to be found somewhat less frequently than one time out of four in the case of pieces free from defects. The piece with a 2-inch pitch pocket falls well within this limit for modulus of rupture and work to maximum load. It will be noted that the damage from 5-inch and 6-inch pitch pockets is quite serious in beams of this size.

Group 2—Pitch Pockets in Tension Flange and Between Load Points.—The pitch pockets in this group were not greater in length than four inches and in one case only did the line of failure pass through the pitch pocket.

Group 3—Pitch Pockets in Web Between Support and Load Point.—Beams in this group were tested to ascertain the effect of pitch pockets on the strength in horizontal shear.

The fact that in beam No. 55 (see Fig. 2) the horizontal shear failure passes through the pitch pocket and the further fact that this beam failed at a lower load than did its mate may be taken as an indication that a pitch pocket of this length (4 inches) constitutes a weakening in horizontal shear.

The conclusions reached from these tests are that:

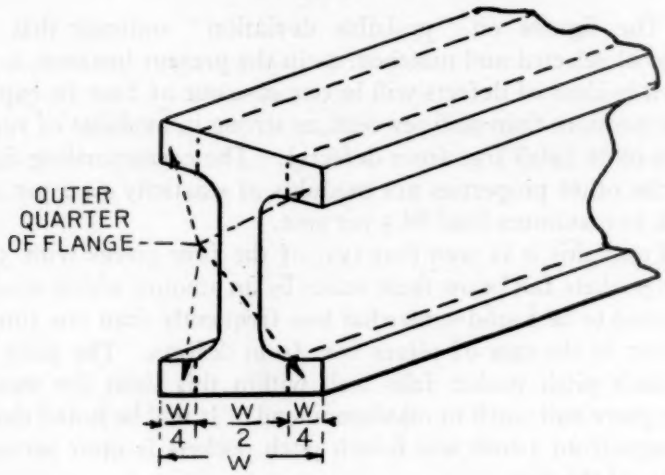
1. The effect of a pitch pocket is dependent on its size and location.

2. The effect of small pitch pockets on strength properties is probably much smaller than has been supposed.

While these tests were on Douglas fir only, there is no reason to suppose that the results are inapplicable to other species.

The tests are not sufficiently numerous to fix definite limits to the size of pitch pockets which may be permitted in different parts of various airplane members. In fact, it may easily be seen that

FIG. 3.



a very large number of tests would be required to cover the possible combinations of size, character and location of such pockets.

The following suggested general specifications for wing beams of I-section (solid or built-up) are based not only on the tests described above but on many years' observation by members of the Forest Products Laboratory of the effect of pitch pockets and various other defects on strength properties and on failures under test.

(*a*) At points where the computed stress multiplied by the loading factor is equal to the maximum allowable stress the beams must be entirely free from pitch pockets.

(*b*) At points where the computed stress multiplied by the loading factor or so-called " factor of safety " does not exceed

90 per cent. of the maximum allowable stress pitch pockets 1½ inches in length and not to exceed ⅛ inch in width or depth may be allowed in any part of the section, except the outer quarters of the flange—provided they do not cause a slope of grain steeper than 1 in 25 in the outer quarters of the flange. No pitch pockets to be allowed in outer quarters of flange.

(*c*) At points where the computed stress, multiplied by the loading factor, does not exceed 70 per cent. of the maximum allowable stress, pitch pockets 2 inches in length and not to exceed ¼ inch in width or depth may occur any place in the section, except in the outer quarters of the flange—provided they do not cause a slope of grain steeper than 1 in 20 in the outer quarter of the flange. No pitch pockets to be allowed in outer quarters of flange.

(*d*) At points where the computed stress, multiplied by the loading factor does not exceed 50 per cent. of the maximum allowable stress, pitch pockets, 1½ inches in length and ¼ inch in width or depth may occur in the outer quarters of the flange and pitch pockets 3 inches in length and ¼ inch in width or depth may occur in any other portion of the section—provided they do not cause a slope of grain steeper than 1 in 15 in the outer quarters of the flange.

(*e*) Pitch pockets in the web may not be closer together than 20 inches; if in the same annual ring they may not be closer together than 40 inches. In other portions of the section these distances may be 10 and 20 inches, respectively.

Asphalt in the United States. (*U. S. Geological Survey, Press Bulletin,* July, 1919.)—Asphalt is widely known and has long been extensively used in road construction, but in recent years many producers of asphalt and allied substances have successfully marketed their products for other uses.

Asphalt is most largely used in this country in paving city streets and country roads, and, though its utilization in road building in 1918 was restricted chiefly to the maintenance of existing pavements and to new construction at cantonments, shipyards, and elsewhere in war work, a larger quantity of paving asphalt, binder, filler, road oil, and flux was made from petroleum and crude native asphalt and sold last year than had been sold in any one year preceding the war.

The uses of asphaltic materials, including both native asphalt

and asphalt made from petroleum, as well as gilsonite, grahamite, and elaterite, in buildings and other structures are manifold. As they are elastic, antiseptic, acid-resistant, and moisture proof, these materials are being widely employed for use in flooring and roofing, in waterproof coating, and in electric insulation, as well as in the manufacture of varnish, paint, and putty. Although these materials have been marketed for relatively few years they are in general demand among contractors and engineers and their use is rapidly increasing.

Gilsonite, the purest known hydrocarbon, has found great favor in the rubber industry. As pure rubber is sensitive to heat and cold it can not be used advantageously for making products that are exposed to extreme temperatures, but when it is mixed with gilsonite and the mixture is vulcanized the rubber undergoes changes in composition that enable it to resist variations in temperature as well as oxidation. The product of this mixture, which is called mineral rubber, is well adapted to outdoor use, and the demand for it is increasing.

Ozokerite, a native paraffin, is utilized in the manufacture of leather polish, sealing wax, electrotypers' wax, candles, electric insulation, carbon paper, and ink. Prior to the war all the ozokerite used in this country was imported, chiefly from Galicia, but when that source of supply was cut off a search was made for deposits in the United States, and this hydrocarbon first entered the market from domestic deposits in 1916. Most of the output in 1918 was used as an acid-proof coating for electrotypers' plates.

American Chemical Society. (*A. C. S. News Service*, July 14, 1919.)—The fifty-eighth meeting of the American Chemical Society will be held in the city of Philadelphia from September 2nd to 6th inclusive. The first general meeting will be held on Wednesday morning, September 3rd. One of the features will be the first session of the newly organized dye section. There will be a joint session of this section with the Division of Industrial Chemists and Industrial Engineers to consider a proposal to revise the patent laws. It has been suggested that the charging of a nominal annual renewal fee would compel many patentees to exploit their patents rather than to permit them to remain undeveloped for many years. Special arrangements have been made to give to all delegates to the convention access to the various chemical plants in and around Philadelphia. An opportunity to view the large munition works will also be given the visitors.

RECENT PROGRESS IN THE MANUFACTURE OF GLASSES FOR PROTECTING THE EYE FROM INJURIOUS RADIATIONS.*

BY

W. W. COBLENTZ, Ph.D.

Associate Physicist, Bureau of Standards.

THE old saying that it is an ill wind that blows no one good, is well illustrated in the manufacture of optical glass.

One of the chief requirements in the manufacture of optical instruments is a colorless glass. Iron is the most common substance which causes discoloration in, and hence diminishes, the transmission of optical glass. On the other hand, iron impurities in glass have a marked absorption in the infra-red, the maximum being at about 1μ. This property may, therefore, be utilized in the manufacture of glasses for protecting the eye from infra-red rays.

Although it has not been definitely proven that infra-red rays are injurious to the eye, there seems to be a feeling that protection from these rays should be provided. Fortunately this can be done easily and cheaply. And now the most pampered can be provided with glasses which not only give protection from rays which are known to be injurious, but also supply the most exacting demands as to color, etc.

It is of interest to consider the transmissive properties of various glasses which, used separately or in combination, protect the eye from injurious radiations—particularly from ultra-violet rays.

The ideal glass would be one which absorbs all the ultra-violet and infra-red, and transmits only the visible rays, by an amount sufficient to prevent irritation and injury to the eye.

Four years ago the question of providing glasses for protecting the eye from injurious radiations was practically new and untouched. At that time the feeling was expressed [1] that: "It appears as though in the near future glasses fulfilling every

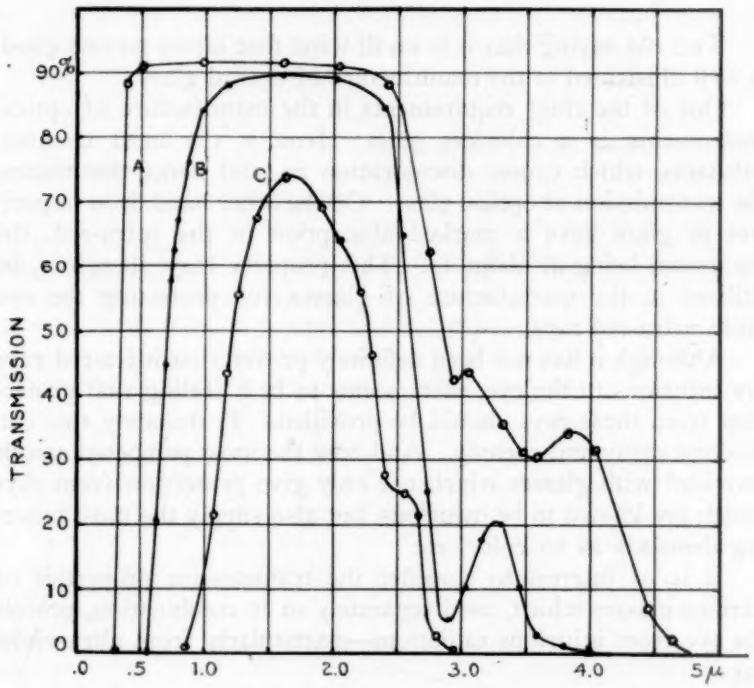
* Communicated by the Author.

[1] JOUR. FRANKLIN INSTITUTE, May, 1913.

requirement will be obtainable, and it speaks well for American enterprise to be willing to spend a few dollars in attempting to produce devices for safeguarding the health and contentment of the public."

In the meantime, this prediction has become a reality. The subject of eye protection has become national in importance, and manufacturers of eye protective glasses are meeting the most stringent requirements.

FIG. 1.



The variety of ways in which various manufacturers of eye-protective glasses fulfill these requirements, will be noticed in connection with the transmissive properties of various glasses, which will now be discussed. In most cases these glasses were about 2 mm. in thickness. More detailed data may be obtained by consulting the original paper.[2]

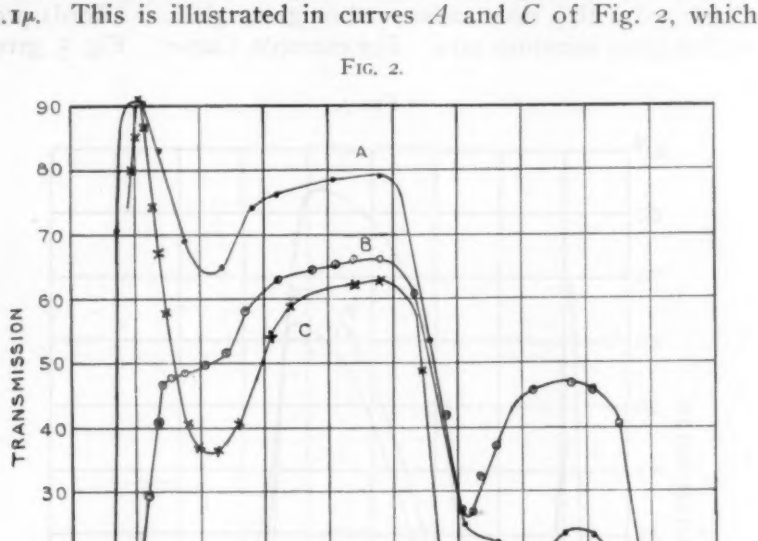
Colorless Glass.—It is of interest to note the characteristics

[2] *Bull. Bur. Standards*, 14, p. 663, 1918.

of optically colorless glass. Curve *A*, Fig. 1, gives the transmission of a sample of white crown glass which transmits ultra-violet to about 0.3μ and infra-red to about 4.8μ. The shallow absorption bands at 2.9μ and 3.6μ are characteristic of glasses.

The presence of iron impurities produces a marked change in the transmission of a glass with an absorption band at about 1.1μ. This is illustrated in curves *A* and *C* of Fig. 2, which

FIG. 2.



gives the transmission of window glass. Viewed edgewise, such glass appears tinged green.

Red Glass.—Curve *B*, Fig. 1, shows that red glass absorbs the ultra-violet and most of the visible rays. But it affords practically no more protection from infra-red rays than does clear glass.

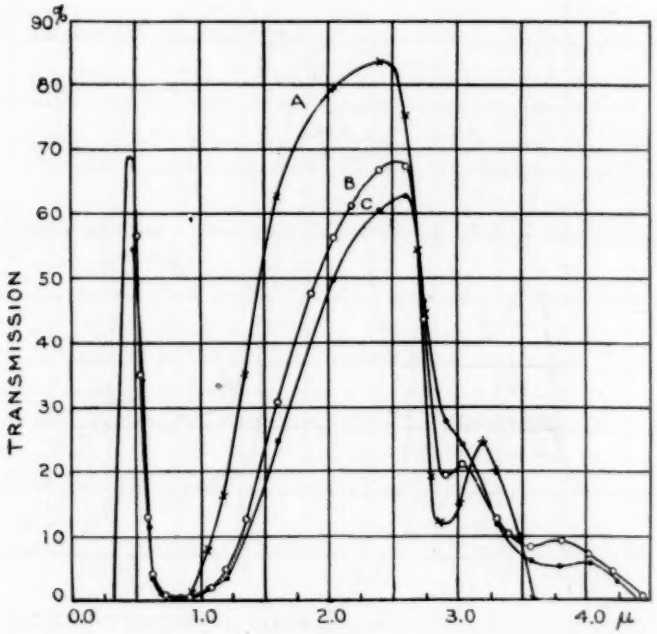
Amber Glass.—As illustrated in Curve *B*, Fig. 2, amber glass absorbs the ultra-violet and some of the visible spectrum. Iron impurities produce an absorption band at 1.1μ. Aqueous solutions of iron alum have an absorption band at about 1μ.

Green Glass.—Curves *A*, *B* and *C*, Fig. 3, show that green

glass is opaque to the ultra-violet and has a wide absorption band in the region of 1μ. In combination with other glasses, it affords suitable protection from injurious rays.

Blue Glass.—Curve *A*, Fig. 4, gives the transmission of a sample of cobalt blue glass. In spite of the fact that blue glasses transmit ultra-violet, they are used in some high temperature work. Combined with a deep amber, red or green glass, it affords protection from injurious rays. For example, Curve *C*, Fig. 5, gives

FIG. 3.



the transmission of a combination of several red and blue glasses used in arc welding. Curve *D*, Fig. 5, gives the transmission of a combination of a flashed red, a green and a blue glass used in oxy-acetylene welding. These two combinations were found to reduce the intensity of the visible rays by a suitable amount, and they afford proper protection from the infra-red and especially the ultra-violet. (In these two curves, *C*, *D*, Fig. 5, the transmissions are double the values indicated on the scale.)

Sage Green and Blue Green.—Two excellent glasses for

FIG. 4.

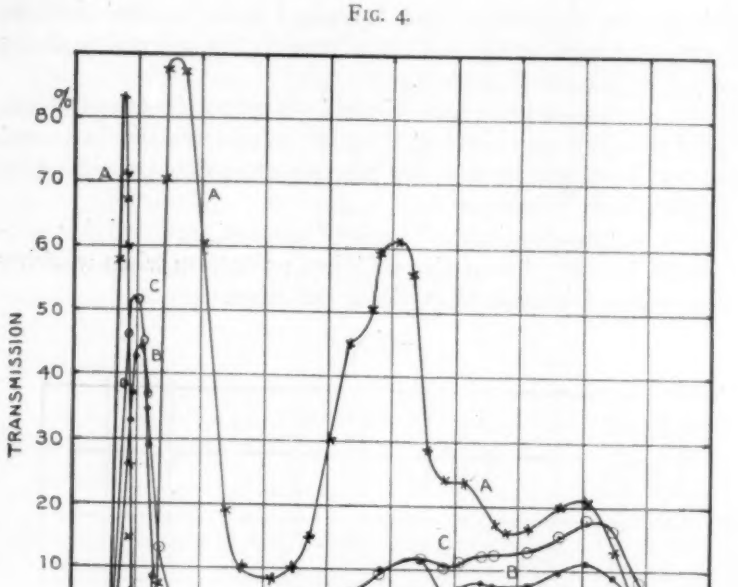
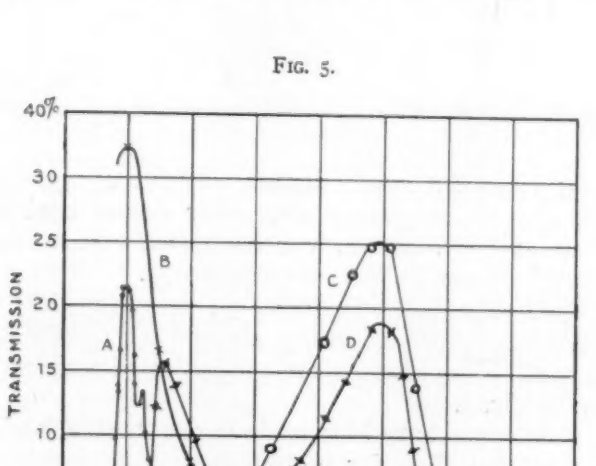

TRANSMISSION
%
80
70
60
50
40
30
20
10
0
0.0
1.0
2.0
3.0
4.0
5.0 μ
A
A
C
B
A
C
B

FIG. 5.

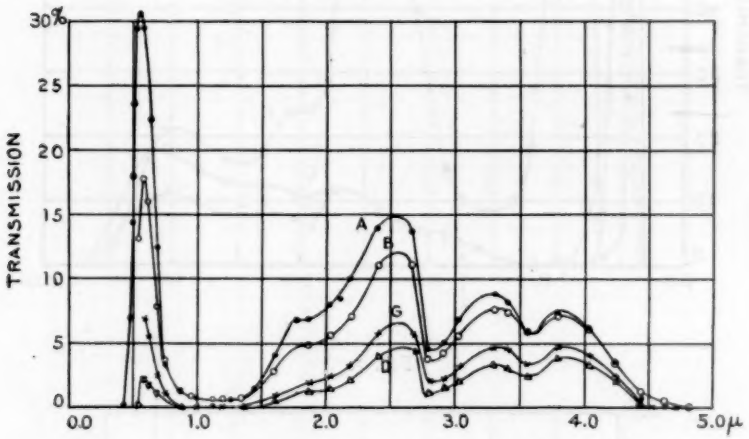

TRANSMISSION
40%
30
25
20
15
10
5
0
0.0
1.0
2.0
3.0
4.0 μ
A
B
C
D

absorbing the ultra-violet and infra-red are Crookes' ferrous sage green (American Optical Co., Curve *B*, Fig. 4), and Corning *C*, 124 *J.A.*, Curve *C*, Fig. 4.

Gold Leaf.—A thin film of gold on glass (obtained from *A.O.C.*; see Curves *A* and *B*, Fig. 5) eliminates the infra-red and ultra-violet, and by selecting the proper density provides also protection from visual rays.

Black Glass.—Ordinary "smoke" glasses are good for outdoor wear, but they do not give sufficient protection when working near sources of intense ultra-violet radiation.

FIG. 6.



Judging from the small number of "black" glasses submitted for test, in comparison with other glasses used in oxy-acetylene welding and cutting, it would appear that the so-called deep "black" glasses are not used extensively.

Noviweld.—This is a commercial eye-protective glass (Corning Gl. Works) which effectively absorbs the ultra-violet and infra-red rays. The transmissive properties of various shades are shown in Fig. 6.

Dyes.—Attempts have been made to use dyed celluloid films instead of colored glass for protection against harmful radiations. In this manner it seems feasible to absorb the ultra-violet and visible rays. But the writer knows of no dye which has marked absorption throughout the infra-red. As shown in Curve *C*, Fig. 1, a sheet of celluloid which is dyed so as to be

opaque to the visible and ultra-violet, is quite transparent in the infra-red.

The published data of others [3] shows that dyes (*e.g.*, green and violet dyes) which absorb the yellow and red become quite transparent in the infra-red. Hence, unless a dye is found which absorbs the infra-red, the outlook for substituting dyed films for colored glasses, for absorbing the infra-red, is not very encouraging.

The foregoing is a brief description of the characteristics of glasses readily obtainable, which singly or in combination afford protection from injurious radiations.

WASHINGTON, D. C., April 15, 1919.

[3] *Pfund. Zeitschr. Wiss. Photog.*, **12**, p. 341, 1913; Johnson and Spence, *Phys. Rev.* (2). **5**, p. 349, 1915.

Precious Stones in the United States. (*U. S. Geological Survey, Press Bulletin*, July, 1919.)—The value of the precious stones annually produced in the United States from the beginning of this century to 1914 has been about one-third of a million dollars. In 1914 and in every year since, the annual value of the output has dropped considerably, and in 1918 it dropped to $106,523, the lowest reported since the United States Geological Survey began to collect statistics of gem production, in 1883, with the single exception of 1896, when it was $97,850.

The report on the production of precious stones in 1918, just published by the Survey, ascribes the decrease in the value of the precious stones produced to the military enlistment of many gem miners, the general scarcity of labor, and the poor market.

The output consisted chiefly of the sapphire variety of corundum, which is nearly all used as mechanical bearings in watches and other instruments that require practically nonwearing frictionless bearings. Other less valuable and softer minerals used for this purpose are garnet and some forms of hard, compact silica, known as agate and chalcedony. The annual value of the output of the four gem minerals, corundum, quartz, tourmaline, and turquoise, amounts to over four-fifths of the total value of all the precious stones produced in the United States.

Montana, Nevada, California, Colorado, Maine, and Arizona are the chief gem-producing States, but from 20 to 30 States annually report some production.

Several relatively large diamonds were found in Arkansas in 1918, notably a canary-colored octahedron weighing nearly 18 carats and a number of smaller stones weighing several carats each.

The value of all the diamonds produced in the United States, however, in no year exceeds a few thousand dollars.

The report also records the finding of two large diamonds in South Africa, weighing about three ounces each. It is estimated that about half the diamonds in the world are owned in the United States and that their value is over a billion dollars. With the elimination of competition from German Southwest Africa 95 per cent. of the world's production of diamonds will be under the control of the De Beers Consolidated Mines Co. and its selling agents.

The report gives a short list of the industrial uses of precious stones of gem quality and full descriptions of the Iceland spar variety of calcite and of optical fluorite, states the special uses and necessary qualifications of the material, and includes lists of buyers.

The report on the production of precious stones in 1917 contains a full list of gem names, each followed by the name of the mineral species to which the gem belongs. A second list gives names of the mineral species, each followed by all the names of the corresponding gem.

Central-Station Heating in Detroit. J. H. WALKER. (*The American Society of Mechanical Engineers,* Spring Meeting, June, 1919.)—The general problem of the utilization of the heat ordinarily discharged to the condensing water in a central electric generating station is discussed. The impossibility of its complete utilization for the purpose of heating buildings and the difficulties in the way of even its partial utilization are pointed out, with particular reference to conditions existing in Detroit, Michigan.

The development of the central heating system of the Detroit Edison Company is traced, showing how the use of exhaust steam for heating was abandoned in favor of live steam. The reasons why it is more commercially expedient under the existing local condition to supply live steam to the heating system and to generate all electric current in the condensing stations are also fully brought out.

The paper also describes some interesting features of the central heating system in Detroit, such as the boiler plants, distributing system, underground construction of pipes and tunnels, consumers' installations and meters. Special mention is also made of distribution losses, condensation return lines, and the method of transmitting steam through feeders at high velocities and with large pressure drops.

The paper concludes with a discussion of the advantages of central heating service and of the obstacles to its wider use. It also points out the possibility of operating individual plants in combination with the central plant.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SOME OPTICAL AND PHOTOELECTRICAL PROPERTIES OF MOLYBDENITE.[1]

By W. W. Coblentz and H. Kahler.

[ABSTRACT.]

THIS paper gives data on the transmissivity and the reflectivity of molybdenite; also data upon its change in electrical conductivity, when exposed to thermal radiations of wave-lengths extending from the ultra-violet into the extreme infra-red.

The effect of temperature, humidity, intensity of the exciting light, etc., upon the photoelectrical sensitivity of molybdenite was investigated.

It was found that:

(1) Samples of molybdenite, obtained from various localities, differ greatly in sensitivity.

(2) There are maxima of sensitivity in the region of 0.73μ, .85μ, 1.02μ, and 1.8μ.

(3) There is no simple law governing the variation in the photoelectric response with variation in intensity of the radiation stimulus.

(4) The increase in photoelectric current with increase in intensity of the incident radiation is greatest for infra-red rays. It is greatest for low intensities of the exciting light and it is greatest on the long wave-length side of the maximum.

(5) The photoelectric sensitivity increases with decrease in temperature. At 70° C. the bands at 1.02μ and 1.8μ have practically disappeared. On the other hand, at liquid air temperatures, the greatest change in electrical conductivity is produced by radiations of wave-lengths between 0.8μ and 0.9μ.

Unlike selenium, molybdenite appears unique in being photoelectrically sensitive to infra-red rays, extending to about 3μ.

* Communicated by the Director.

[1] Scientific Paper No. 338.

A STANDARDIZED METHOD FOR THE DETERMINATION OF SOLIDIFICATION POINTS, ESPECIALLY OF NAPHTHALENE AND PARAFFIN.[2]

By R. M. Wilhelm and J. L. Finkelstein.

[ABSTRACT.]

THIS paper, after a brief treatment of the definitions of melting and freezing points both of pure substances and of mixtures, describes a method of making solidification point determinations of naphthalene. This method was recommended at a conference of Bureau of Standards and U. S. Customs officials and is based on the well-known cooling curve or constant temperature method. The method is shown to be applicable to the determination of the freezing points of paraffin and other substances.

THE STANDARDIZATION OF THE SULPHUR BOILING POINT.[3]

By E. F. Mueller and H. A. Burgess.

[ABSTRACT.]

THIS paper describes experiments made to complete the data which are required for the standardization of the sulphur boiling point as a thermometric fixed point. The precision attainable in calibration of resistance thermometers at the sulphur boiling point is so much higher than the accuracy of the gas thermometer determinations of the temperature that it was considered desirable to standardize the temperature corresponding to normal atmosphere pressure by definition at 444.°60, and the data from which this figure was deduced are given.

Experiments were made to determine the effects of type of radiation shield, the type of boiling apparatus and purity of sulphur, upon the temperature assumed by a resistance thermometer in the sulphur vapor. The conclusions reached were that if a radiation shield is to be effective, its inner surface should be a good radiator, that, within wide limits, the temperature is independent of the type of boiling apparatus used, and that sulphur of a high degree of purity, which is however readily obtainable, should be used.

The relation between the vapor pressure of sulphur and the

---

[2] Scientific Paper No. 340.

[3] Scientific Paper No. 339.

temperature, over the pressure range from 700 to 800 mm. was determined with a precision of 0.°01 or better. The result of this work is the equation:

$t = 444.°60 + 0.0910\ (p-760) - 0.000049\ (p-760)^2$ where t is the temperature in Centigrade degrees, assumed by a properly shielded resistance thermometer in the standard form of sulphur boiling apparatus, and p is the pressure, expressed in equivalent millimetres of mercury at 0° and under standard gravity ($g = 980.665$). In an appendix are given the specifications for a proposed standardization of the sulphur boiling point.

METALLIC COATINGS FOR THE RUST-PROOFING OF IRON AND STEEL.[4]

[ABSTRACT.]

STEEL is protected against corrosion in a great variety of ways, including metallic and related coatings, paints, lacquers, varnishes, enamels, etc. The circular deals with the various types of metallic coatings, including those closely related in their nature and method of production (oxide and similar coatings). The methods of application and characteristics of the different metal coatings are discussed and it is shown that zinc, because of its electro-positive nature with respect to iron, is the metal to be relied upon when protection against corrosion is the prime consideration. Other considerations, *e.g.*, freedom from toxic effects, *e.g.*, for food containers, often lead to the choice of some metal other than zinc for a coating.

The structure and uniformity of distribution of the different classes of zinc coatings are discussed and their bearing upon the behavior in service is pointed out. Of the various methods which are used for the testing of coated materials, the " salt spray " test is by far the most satisfactory. The articles to be tested are exposed to a fine mist of a saturated salt solution and the length of time that they successfully withstand this severe exposure is a fair index of the service life that may be expected for the specimen. This test while not entirely satisfactory is the best which has yet been suggested.

A series of recommendations concerning the choice of protective metallic coatings for various types of works is given, together with a good working bibliography of the subject.

[4] Circular No. 80.

LEAKAGE RESISTANCE OF ELECTRIC RAILWAY ROADBEDS AND ITS RELATION TO ELECTROLYSIS.*

By E. R. Shepard.

[ABSTRACT.]

TECHNOLOGIC Paper 127 of the Bureau of Standards, entitled "Leakage Resistance of Electric Railway Roadbeds and its Relation to Electrolysis," by E. R. Shepard, Electrical Engineer, gives the result of more than three years of electrical resistance measurements on different types of roadbeds. Electrolytic damage to underground piping systems is caused from the escape of current from the rails of electric lines and the resistance of the roadbed is an important factor in the amount of current which may escape.

Short sections of fourteen common types of roadbeds were constructed on the grounds of the Bureau of Standards and resistance measurements under varying weather conditions were carried on for a period of three years. Some measurements were also made on a number of city lines in and about Washington, both open track and several types of roadbed in paved streets being investigated. Through the coöperation of the United States Forest Products Laboratory at Madison, Wisconsin, measurements were also made on several sections of test track on the Chicago, Milwaukee and St. Paul Railway where railroad ties subjected to several different kinds of preservatives were employed. The results of these measurements are given in tabular and graphical form, and the following conclusions have been drawn:

1. Roadbeds constructed with solid concrete ballast and vitrified brick or other non-porous pavements have a low leakage resistance to earth which is affected only moderately by seasonal and weather changes. There is little difference between wood and steel ties in their effect on the resistance of roadbeds of this kind. Insulation is not of practical value in reducing leakage current from such roadbeds. The resistance of single roadbed of this type is from 0.2 to 0.5 ohm per 1000 feet, under ordinary conditions, but may be two or three times this when the ballast is frozen to a depth of 1 foot or more. For double roadbed of this type the resistance is approximately 70 per cent. of that for single roadbed, or the leakage from double track would be about 40 to 50 per cent. greater than from single track.

*Technical Paper No. 127.

2. Roadbeds constructed with a foundation of clean crushed stone under concrete paving base have a much higher resistance than roadbeds with a solid concrete ballast. In the case of the experimental roadbed the ratio was found to be about 3 to 1. Roadbeds with a full crushed stone ballast and a Tarvia finish have a very high leakage resistance which is of the order of 2 to 5 ohms per 1000 feet of single track. The leakage from a double roadbed of this type and other high-resistance types is from 80 to 100 per cent. greater.

3. The resistance of earth roadbed in which the ties are imbedded and therefore kept in moist condition is much lower than that of open construction roadbed, being from 1 to 1½ ohms per 1000 feet of single track under normal conditions and considerably more when the ground is frozen.

4. The resistance of roadbeds of open construction is subject to wide variation depending upon the condition of the ties and ballast. In very dry weather with good ballast the resistance will be 10 to 15 ohms or even more per 1000 feet of single track, but in wet weather it will drop to from 3 to 5 ohms. Cinder, gravel and particularly crushed stone, when used as a ballast in open-track construction, produce very high-resistance roadbeds. Earth has a tendency to keep the ties moist and therefore to increase the leakage. Open-construction track is often considered to be insulated from the earth, but this is not strictly true. Assuming a potential difference between the track and the earth of 5 volts and a leakage resistance of 10 ohms per 1000 feet the total leakage per mile would be 2.64 amp. This small leakage current would not ordinarily be harmful to underground structures in the vicinity of the track.

THE CONSTITUTION OF ALUMINUM AND ITS LIGHT ALLOYS WITH COPPER AND WITH ALUMINUM.[1]

By P. D. Merica, R. G. Waltenberg and J. R. Freeman, Jr.

[ABSTRACT.]

THE temperature-solubility curves of $CuAl_2$ and of Mg_4Al_3 in aluminum were determined by the method of annealing and microscopic examination. Aluminum dissolves about 4.2 per cent.

[1] Scientific Paper No. 337.

of copper as $CuAl_2$ at 525° C. and about 12.5 per cent. of magnesium as Mg_4Al_3 at 450° C.

The solubility of both compounds decreases with decreasing temperature. At 300° C. aluminum dissolves only 1 per cent. of copper as $CuAl_2$ and slightly less than 5.9 per cent. of magnesium as Mg_4Al_3.

The structural identification of the various constituents, $FeAl_3$, $CuAl_2$, Mg_4Al_3, found in alloys with magnesium and with copper is described, and a constituent is noted in all light aluminum alloys containing magnesium which is believed to be Mg_2Si.

The solubility of iron as $FeAl_3$ in aluminum is at all temperatures less than 0.15 per cent.

Small amounts of silicon up to from 0.12 to 0.20 per cent. are dissolved by aluminum at the eutectic temperature but are reprecipitated upon cooling corresponding to the diminished solubility for silicon of aluminum at lower temperatures.

Silicon in the usual commercial amounts is probably present as a compound of iron and silicon together with some aluminum. The composition of this compound is not known, but it separates out with aluminum and $FeAl_3$ at an invariant point at 610° C.

Large Engine and Small Power. (*National Engineer,* vol. xxiii, No. 7, p. 325, July, 1919.)—The *Savannah,* the first ocean-going ship to use steam engine propulsion (1819), shows the difference between then and now of boiler pressures available, so much so that comparatively large engines were needed to develop what nowadays is considered small power. The engine of the *Savannah* was equipped with a cylinder 40 inches in diameter and 60-inch stroke, built by Stephen Vail, near Morristown, N. J. The boilers were constructed to carry a steam pressure of 20 inches, registered by a mercury gauge, and were built by Daniel Tod, of Elizabeth, N. J. The paddle wheels could be folded up like a fan and stored on deck when the sea was too rough for their use. Although both sail and steam power was used, the vessel made, on trial, ten miles with and against tide in one hour and fifty minutes. This equipment and performance of the *Savannah* and that of the *Mauretania* tells the story of achievement in marine performance.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE CONSTITUTION OF CAPSAICIN, THE PUNGENT PRINCIPLE OF CAPSICUM.[1]

By E. K. Nelson.

[ABSTRACT.]

MATERIAL for this research was prepared according to Micko's method for the preparation of capsaicin. The best yield obtained was 50 grams of capsaicin from 50 pounds of very hot cayenne pepper.

Methylation of capsaicin produces methyl capsaicin, and oxidation of this by means of alkaline potassium permanganate leads to veratric acid. Hydrolysis under pressure breaks capsaicin down into vanillyl amine (4-hydroxy-3-methoxy benzylamine) and a decylenic acid. That the decylenic acid in the molecule of capsaicin does not possess a normal chain is proven by the fact that on hydrogenation normal decylic acid (capric acid) is not formed, but an isomeric decylic acid melting lower than capric acid.

Capsaicin is therefore a condensation product of vanillyl amine and a decylenic acid. The synthesis of substances analogous to capsaicin is being undertaken, and will form the subject of a later communication. Some of these substances already prepared are extremely pungent.

THE ZINC CONTENT OF SOME FOOD PRODUCTS.[2]

By Victor Birckner.

[ABSTRACT.]

EXAMINATION of the ash disclosed the presence of appreciable quantities of zinc in many food products. Bakers' yeast, wheat, oats, corn, barley, rye, and rice contained from 415 to 15 mg. of zinc per 1000 grams of fresh substances. In ordinary

* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, **41**: 1115-21, July, 1919.

[2] Published in *J. Biol. Chem.*, **38**: 191–203. June. 1919.

market milk about 4.2 mg. of zinc was found per 1000 grams, and in human milk from 6 to 14 mg. per 1000 grams. Practically all the zinc in hens' eggs, amounting to about 0.005 per cent. of the yolk, occurred in the yolk.

From its constant occurrence in the yolk of eggs as well as in cows' and human milk, it is inferred that the element zinc exerts an important nutritive function, the nature of which is not at present understood.

Tumbler Switches. (*Scientific American*, vol. cxxi, No. 3, p. 53, July 19, 1919.)—While the tumbler switch has long been the standard in most countries abroad, the United States has persistently stuck to the snap switch and the push-button switch. Of late, however, the advantages of the tumbler switch have come to be realized, and manufacturers have started in on the production of such switches. Some of the designs offered are typically English, while others are distinctly American in their simplicity of design. The new switches of the tumbler type are exceptionally attractive in appearance and convenient to use. A single button operates the mechanism, which is of the quick make-and-break variety. Incidentally, the tumbler switch is self-indicating, the position of the lever indicating whether the switch is "on" or "off" at a glance.

Air Fans for Driving Electric Generators on Airplanes. G. FRANCIS GRAY, JOHN W. REED AND P. N. ELDERKIN. (*The American Society of Mechanical Engineers*, Spring Meeting, June, 1919.)—The authors describe the method employed by the Radio Development Section of the War Department in testing air fans used for driving the electric generators usually installed on airplanes for radio communication. They also discuss at some length the various types of air fans and present numerous photographs and curves clearly illustrating the construction of the fans and their operating characteristics.

The difficulty of the problem lay in designing a fan which would turn at constant speed in the air streams of widely varying speed set up by the airplane in flight. The various types of fans tested were: Fixed-blade fans of special blade shape; fixed-blade fans with wind brakes centrifugally regulated; fixed-blade fans using a friction clutch or a friction brake centrifugally regulated, and pivoted-blade fans in which the pitch is centrifugally regulated.

NOTES FROM THE U. S. BUREAU OF MINES.*

METHOD OF ADMINISTERING LEASES OF IRON ORE DEPOSITS BELONGING TO THE STATE OF MINNESOTA.[1]

By J. R. Finlay.

AT the request of the State Auditor of Minnesota the Bureau of Mines undertook an investigation of the methods of administering State leases of iron ore deposits. As the material in the report submitted is of great general interest it has been published for the benefit of the mining industry in general. The State of Minnesota owns 40,400 acres of land known to be ore-bearing, containing 168,000,000 tons of iron ore of present commercial grade. These ores are mainly leased under agreements that expire at the average date of 1952, under a royalty of 25 cents per ton and an agreement that the lessee shall work the mines in a manner which is customary in skilful mining. Two points are therefore involved: whether the mines are actually being so worked, and on what ores shall the State demand royalties. The ores range in grade from 65 per cent. down to 30 per cent. iron, average ore shipments are 56 per cent. iron, and it is therefore practicable to mix higher grade ores with lower grades, providing the latter are above the limit of profit. The investigation shows that ores under 48 per cent. iron dry or 42 per cent natural are not profitable to work under present conditions. Concentrating ores which run only 30 per cent. iron up to 50 per cent. iron is only an apparent exception, since in this case it pays to add to the cost of production in order to reduce the cost of transportation. Whether the "paint rock," which averages about 50 per cent. iron, is an ore is a matter of dispute between State officials and lessees. The conclusion of the author is that under present conditions it cannot be considered as ore, and its removal in underground operations is not justified. In open cut operations it has to be removed anyway, and it can be kept segregated in case it may eventua'ly prove of value. The

* Communicated by the Director.

[1] Technical paper 222.

taconite or "iron formation" averages about 35 per cent. iron. At the eastern end of the Mesabi range there is an area in which the taconite has been so magnetized that its concentration by magnetic processes is possible. At the present time the capital investment required to make this separation is too large compared to the margin of profit, but it is not at all impossible that at some future time the value of the product or the cost of construction of the plant may be so altered as to make this material commercial ore. The author is confident that enough ore is available in Minnesota to keep up shipments of the present grade for 30 years. There is not much ground for anxiety as to the conserving of these possible sources of future wealth. The ores are indestructible and the great bulk of the formations are not likely to be so mixed by mining operations as to become utterly inaccessible. In some instances ores leased by the State at a royalty of 25 cents per ton have been sub-leased at a higher royalty and it is not fair to the people of the State for the operator to refuse to mine ore that would meet the 25 cents royalty but will not meet the higher royalty. This can only be met by negotiations between the operators and lessees for modification of royalty conditions. The conclusion of the author is that the State lands, so far as the iron mines are concerned, have all been well and properly administered.

ELECTRODEPOSITION OF GOLD AND SILVER FROM CYANIDE SOLUTION.[1]

By S. B. Christy.

ELECTROLYTIC precipitation of gold and silver from cyanide solution would seem, on the face of it, not to offer any great difficulty since the electro-plating of gold and silver is a well-developed art. But as a matter of fact, a great many practical difficulties develop since the solutions resulting from the cyanide treatment of ores are a rather complex mixture of salts, and no really satisfactory substance has been found for the insoluble anode that must be used. The precipitation of these metals by the use of zinc shavings or dust is so relatively simple that their electro-deposition has never come into general use, although a patent for such a process was issued 20 years before the McArthur

[1] Bulletin 150.

and Forrest patent on the cyanide process of gold recovery appeared. Meanwhile a number of processes for this purpose have been patented. At intervals over a period of 20 years Professor Christy studied the problem and took out a patent for a process of his own in 1900. Like the other patented processes it never came into general use, but in the course of his investigations Professor Christy performed an enormous amount of experimental work, which is recorded in this monograph. This careful record of experiments covering all phases of the subject under investigation is of great value for reference for investigators in the field of electrolytic deposition of metals.

ELECTRIC FURNACE LABORATORY EQUIPMENT AT SEATTLE STATION, U. S. BUREAU OF MINES.

By Charles D. Grier.

THE power supply equipment of the electric furnace laboratory at the Seattle Station, which has recently been installed, consists of two 140 kva. transformers and two duplex induction voltage regulators for supplying low tension current, and a three-panel switchboard and bus bar system for its distribution. As different furnaces are built to fit the needs of the various problems presented, connections can be made between the bus bar system and the furnaces, and either single or two-phase power supplied at any voltage between 35 and 484 volts.

The transformers and regulators are connected on the primary side to a 2,500-volt line from the Municipal Power Plant. The secondary coil of each transformer is divided into four sections, each of which has a normal voltage of 78 volts. The voltage of each of the secondary coils of the regulators can be made anything from 43 volts "boosting" to 43 volts "bucking," according to the relative position of the coils. Each transformer secondary coil is connected in series with a secondary coil in one of the regulators and it may be considered that the combination of each transformer and its regulator is a transformer with four coils, each capable of delivering 450 amperes at any voltage between 35 and 121 volts.

On the switchboard are mounted high and low tension voltmetres, ammetres for both phases, a power factor metre indicat-

ing and recording wattmetres and a watthour metre. Various switches permit connecting the transformers both on a single phase or one on each of the two phases, on the primary side, and of connecting the secondary coils in multiple, series, or series-multiple. The motors which operate the voltage regulators are controlled by push-button switches on the board, so that control of the furnace voltage within wide limits is effected by merely pressing buttons on the switchboard, and changes through the extreme range involve only two very simple switch changes.

The capacity of the equipment is a maximum when the regulators are boosting the maximum. At such a time the rated capacity is 435 kva. At the lowest voltage the capacity is 126 kva. The apparatus is therefore capable of delivering as much power as is used by small commercial furnaces. This capacity, the wide voltage range and the simplicity of control, make the equipment a remarkable group of apparatus.

CARBON BLACK FROM NATURAL GAS.

By G. St. J. Perrott and R. O. Neal.

AN investigation of the carbon black industry has been undertaken by the United States Bureau of Mines as a result of economic issues brought up during the war. Considerable field work has been done. Plants in Louisiana, Oklahoma, and West Virginia have been studied by Bureau engineers. The uses of carbon black have been carefully investigated with the idea of determining the properties of the product which users of carbon black demand, and with an attempt at designating in which of these uses carbon black is essential and in which a substitute material might be employed. Microscopic and chemical examination of a large number of blacks is being made and test methods studied with a view to finding the reason for the very different behavior exhibited by different blacks.

In the present process of manufacture, carbon black is produced by burning natural gas with an insufficient supply of air for complete combustion and collecting the liberated carbon on a metal surface. Manufacturers of carbon black believe that this process is the only one in practical operation which produces a carbon black suitable for the ink trade and rubber industry. Over

10,000,000 pounds annually are used in ink manufacturing; 20,000,000 pounds annually are used in making automobile tires.

A Bureau of Mines bulletin on the Manufacture, Properties and Uses of Carbon Black is in process of preparation.

MINOR NOTES.

Rare Metals.—The investigation of the metallurgy of Wulfenite, made at the Golden Station of the Bureau, has been completed and a report upon it will shortly be issued. The work upon the production of zirconium from its ores is almost completed. A bibliography of vanadium is also in course of preparation.

Fire Extinguisher Liquids.—An investigation of the various types of commercial carbon tetrachloride fire extinguisher liquids, made at the Pittsburgh station of the Bureau, has demonstrated that when these liquids strike burning wood or red-hot iron the carbon tetrachloride is partly decomposed and small amounts of toxic gases are formed, so that such extinguishers must be used with caution in confined spaces.

Army Gas Masks in Fires.—Tests of the army type gas mask for use in the irritating and choking smokes produced in fires show that it offers complete protection against these, but allows carbon monoxide to pass through. The coöperation of the fire chiefs of the principal cities was secured in making the investigation. A report of this investigation will shortly be published. These masks have also been tested in railway tunnels, and the results show that they should be of considerable use to engine men when passing through tunnels.

Carbon Determination.—A laboratory method for the determination of graphitic carbon in the presence of amorphous carbon has been standardized at the Pittsburgh station of the Bureau, and is now being checked on a large number of natural graphites and amorphous carbon in the form of coal. The method gives promise of being suitable for the direct quantitative determination of graphitic carbon, which up to the present time has always been an uncertain indirect determination. A laboratory method for the determination of the various forms of sulphur in coal has been tried on a number of typical samples of Eastern coal with very satisfactory results.

Corrosion of Rifle Barrels.—An investigation of the after-

corrosion of rifle barrels is in progress at the Pittsburgh station, in coöperation with the Ordnance Bureau of the War Department. The investigation is not yet completed, but the indications from the work already done are that corrosion is due to solid products of combustion that can only be removed by alkali or organic solvents.

Steam Boiler Tests.—The boiler tests which have been made by the Bureau's engineers for the Emergency Fleet Corporation at Erie, Pa., with such excellent results to date, are to be continued. A series of tests has been started in which oil is used as the fuel, and when the series is completed, a powdered coal test will be made in coöperation with the Erie City Iron Works. A series of tests on the use of coke for house heating purposes is now in progress, comparative tests being made with anthracite. An investigation has been started to determine the cause of the incrustation of boiler tubes when using underfeed stokers.

Phosphorous in Iron Ores.—An investigation has been started by the Minneapolis station to determine whether it is feasible to leach out the phosphorous from medium and high phosphorous iron ores. In connection with this an attempt will be made to develop a standard method for the determination of phosphorus in iron ores that will be satisfactory to both buyers and sellers.

Mining Conditions Abroad.—George S. Rice, Chief Mining Engineer of the Bureau, has returned from an extended investigation of mining conditions in the Saar and Rhine Valley districts, France, Belgium and Great Britain, and reports that the shortage of fuel that prevailed during the war still continues and there is probability of a still more serious deficiency unless the United States increases its exports. This is due more to the general unrest of labor and the increase in the cost of production (which are 75 to 150 per cent. above those prevailing in 1913) than to the physical destruction of coal mines and their equipment. In Great Britain the working hours underground have been reduced from 8 hours to 7, effective July 16, and Sir Auckland Geddes has made the statement that this will result in a production for 1920 of 70,000,000 tons less than in 1913, and an increase in price to the consumer. Meanwhile notice has been given in the House of Commons that the price is to be raised $1.50 per ton on July 16. This curtailing in output and increase in price in England, coupled with a shortage of coal in western and central Europe, where the various countries need 50,000,000 tons per year over their normal

pre-war sources of supply, from countries other than Great Britain. France alone needs 20,000,000 tons per year. The best estimates are that Great Britain will be able to export somewhere between 7,000,000 and 25,000,000 tons in 1919 to all foreign countries. There will therefore be a deficit of somewhere around 40,000,000 tons of fuel, for which the United States is the only visible source of supply.

The mines destroyed by the Germans in the Nord-Pas de Calais coal fields produced 20,000,000 tons of coal per year. It will take two to five years to get these mines in working condition and ten years to completely restore the production rate. The taking over by France of Alsace and Lorraine and its occupation of the Saar Valley will yield a certain amount of coal to make up this deficiency, but as a large part of the output of these districts is used locally the amount that can be counted on from these sources is uncertain as yet, though it is reasonably certain that it will nowhere near make up for the shortage in the Nord-Pas de Calais district. The mines in Belgium were not injured, but there is a shortage of skilled miners, and general labor conditions are such that there is likely to be a deficiency of 40 per cent. of the output as compared with pre-war figures. Half of Spain's coal is normally imported from England, eight-tenths of Holland's coal is imported largely from Germany. Norway, Sweden and Denmark have all heavily drawn on Great Britain for coal. Germany's principal coal-producing district is Westphalia. The only handicap under which this district labors is the general unrest and the weakened condition of the working population through insufficient food. The Ruhr field will probably be called on to deliver a good deal of bituminous coal and coke to France in exchange for the iron ore needed to keep the Ruhr blast furnaces operating. The outlook for a demand for coal for export from the United States is correspondingly bright.

Surplus Electric Power After the War. J. W. BECKMAN. (*American Electro-Chemical Society, Transactions*, 34th General Meeting, 1918.)—It may be the case that we will have a surplus of developed electric power after the world has settled down to a normal stride, this power having been developed in this emergency for the supplying of munitions to us and our allies. It is, therefore, important to face this fact now and consider how it may be avoided or overcome.

It would be an economic waste of the very gravest magnitude if this energy available on the bus-bars should be permitted to be idle, a waste from two points of view: (1) from the point of invested capital in the plant and equipment, and (2) perhaps a still graver waste, from the point of merchandise that could be produced, thus creating values and giving occupation to labor skilled and otherwise helping to supply work to the millions of men who will return to us after the war is won.

It is very apparent that many of the industries which are now operating in connection with the war will have to let up some, and equally certain it is that the power which they thus release will not be absorbed readily by any other industry. This certainly will be the case if we do not as a nation and as individual groups coöperate to extend our foreign markets, *i.e.*, to tap new market possibilities.

Two industries, both of them basic and both of them making products essential to mankind, suggest themselves as being suitable life-savers to the electric developments after the war. One is the iron and steel industry and the second is the fertilizer industry. When I refer to the iron and steel industry, I do not refer either to the electric shaft furnaces in Sweden nor to the electric steel furnaces distributed all through the country.

I think the direct manufacture of steel from iron ore is not out of the realm of the possible, and is one of the important electro-metallurgical developments awaiting a successful solution.

We have already progressed some toward this goal. In the electric shaft furnace low-carbon pig iron is now produced, known as steel pig iron or pig steel. The next step will be the finished steel, suitable for the manufacture of the finished steel product in the shape of ingots and castings. It may be a long step metallurgically to take, but it is one that we should bend all our efforts upon to achieve. If we once accomplish it, we will find the iron industry gradually changing into an electrometallurgical one, consuming enormous amounts of power and stimulating incidentally other industries to activities of very great proportions.

The other industry which would help to consume power is the fertilizer industry. The ingredients necessary in a fertilizer which would be most available for improved manufacture would be nitrogen in some bound form, and phosphoric acid.

THE FRANKLIN INSTITUTE.

LIBRARY NOTES.

PURCHASES.

AULD, S. J. M.—Gas and Flame in Modern Warfare. 1918.

Century of Science in America, With Special Reference to The American Journal of Science, 1818–1919.

HENDERSON, G. G.—Catalysis in Industrial Chemistry. 1919.

MACFARLANE, ALEXANDER.—Lectures on Ten British Physicists of the Nineteenth Century. 1919.

PEELE, ROBERT.—Compressed Air Plant. 1918.

PERNOT, F. E.—Electrical Phenomena in Parallel Conductors. 1918.

RACE, JOSEPH.—Chlorination of Water. 1918.

SILBERSTEIN, L.—Vectorial Mechanics. 1913.

SULLIVAN, T. J.—Sulphuric Acid Handbook. 1918.

WHITESHOT, C. A.—The Oil Well Driller. 1905.

GIFTS.

American Engineering Company, Catalogue of Steering Gear. Philadelphia, Pennsylvania, 1919. (From the Company.)

American Institute of Electrical Engineers, Transactions, Vol. xxxvii, Parts 1 and 2. New York City, New York, 1918. (From Dr. R. B. Owens.)

Armour Institute of Technology, Bulletin of General Information, 1918. Chicago, Illinois, 1918. (From the Institute.)

American Iron and Steel Institute, Annual Statistical Report for 1917. New York City, New York, 1919. (From the Institute.)

American Rolling Mill Company, Catalogue, "The Story of Armco Iron." Middleton, Ohio, 1918. (From the Company.)

American Society of Heating and Ventilating Engineers, Year Book, 1919. (From the Society.)

American Spiral Pipe Works, Catalogue of Pipe and Furnaces. Chicago, Illinois, 1919. (From the Works.)

American Steam Gauge and Valve Manufacturing Company, Catalogue of the American Thompson Improved Indicator. Boston, Massachusetts, 1919. (From the Company.)

Atchison, Topeka and Santa Fé Railway Company, Annual Report for the Year 1918. New York City, New York, 1918. (From the Company.)

Baltimore Health Department, Annual Report, 1917. Baltimore, Maryland, 1919. (From the Department.)

Bogue, Virgil, The Science of Fruit Growing. Albion, New York, 1917. (From the Author.)

Bryn Mawr College, Calendar of Undergraduate and Graduate Courses, 1919. Bryn Mawr, Pennsylvania, 1919. (From the College.)

Buffalo Forge Company, Catalogue No. 410, Section 400. Buffalo, New York, 1918. (From the Company.)

Bureau of Foreign and Domestic Commerce, Statistical Abstract of the United States, 1918. Washington, District of Columbia, 1919. (From the Bureau.)

Cameron, A. S., Steam Pump Works, Bulletins. New York City, New York, 1918. (From the Works.)

Carpenter Steel Company, Catalogue No. 8. Reading, Pennsylvania, 1919. (From the Company.)

Chadburn Telegraph Company of America, Inc., Catalogue of Ship Telegraphs. Troy, New York, 1919. (From the Company.)

Champion Engineering Company, Bulletin No. 106. Kenton, Ohio, 1919. (From the Company.)

Chesapeake Iron Works, Catalogue of Electric Traveling Cranes. Baltimore, Maryland, 1919. (From the Company.)

Chicago, Burlington and Quincy Railroad Company, Sixty-fifth Annual Report of the Board of Directors, 1918. Chicago, Illinois, 1919. (From the Company.)

Colorado Bureau of Mines, Fifteenth Biennial Report for 1917–1918. Denver, Colorado, 1919. (From the Bureau.)

Columbia University, Catalogue, 1918–1919. New York City, New York, 1919. (From the University.)

Connecticut Dynamo Motor Company, Catalogue of Low Voltage Dynamos. Irvington, New Jersey, 1919. (From the Company.)

Daigger, A., and Company, Catalogue of Laboratory Supplies and Chemicals for Chemists and Bacteriologists. Chicago, Illinois, 1919. (From the Company.)

Davison, N. C., Gas Burner and Welding Company, Catalogue of Davison Burners. Pittsburgh, Pennsylvania, 1919. (From the Company.)

Delaware College, Annual Catalogue, 1918–1919. Newark, Delaware, 1919. (From the College.)

Dixon, Joseph, Crucible Company, Graphite, Vol. xx, January to December, inc., 1918. Jersey City, 1919. (From the Company.)

Doehler Die-Castings Company, Catalogue, Do-Di Finished Brass Castings. Brooklyn, New York, 1919. (From the Company.)

Electric Furnace Company, Booklet 5-B. Alliance, Ohio, no date. (From the Company.)

Electric Machinery Company, Bulletin No. 501. Minneapolis, Minnesota, no date. (From the Company.)

Electric Welding Company, Catalogue of Electric Welding by the Elwood Process. Cleveland, Ohio, no date. (From the Company.)

Fellows Gear Shaper Company, Catalogue of Commercial Gear Cutting. Springfield, Vermont, 1919. (From the Company.)

Florida State Geological Survey, Annual Report, 1919. Tallahassee, Florida, 1919. (From the Survey.)

General Fireproofing Company, Catalogue of GF Steel-Tile; Fireproofing Handbook, 6th edition. Youngstown, Ohio, 1918. (From the Company.)

Georgia School of Technology, Catalogue, 1918–1919, Announcements, 1919–1920. Atlanta, Georgia, 1919. (From the School.)

Gifford-Wood Company, Catalogue No. 31. Hudson, New York, 1919. (From the Company.)

Gold Car Heating and Lighting Company, Gold's Handy Reference. New York City, New York, 1919. (From the Company.)

Goldschmidt Thermit Company, Catalogue of Thermit Carbonfree Metals. New York City, New York, no date. (From the Company.)

Greaves-Klusman Tool Company, Catalogue, General Description of G-K Betterments. Cincinnati, Ohio, no date. (From the Company.)

Greene, Tweed and Company, Catalogue of Steam Specialties. New York City, New York, no date. (From the Company.)

Griscom-Russell Company, Bulletins 222-224, 230, 609, 1103. Philadelphia, Pennsylvania, 1919. (From the Company.)

High Speed Hammer Company, "Let Us Shoulder Your Riveting Problems." Rochester, New York, no date. (From the Company.)

Higler, Adam, Ltd., Catalogues of the Abbe Refractometers; Higler Wavelength Spectrometer; Nutting Photometer and the Refractive Index. London, England, 1919. (From the Company.)

Hinde and Dauch Paper Company, Catalogue. Sandusky, Ohio, 1918. (From the Company.)

Hires Turner Glass Company, Catalogue. Philadelphia, Pennsylvania. 1919. (From the Company.)

Hood Manufacturing Company, Catalogue. Seattle, Washington, 1919. (From the Company.)

Hydro-Electric Power Commission of the Province of Ontario, Eleventh Annual Report, 1918. Toronto, Canada, 1919. (From the Commission.)

India Department of Agriculture, Report on the Progress of Agriculture for 1917–1918. Calcutta, India, 1919. (From the Agricultural Adviser.)

Ingersoll Milling Machine Company, Bulletin No. 38. Rockford, Illinois, 1919. (From the Company.)

Jeffrey Manufacturing Company, Catalogue No. 175. Columbus, Ohio, 1919. (From the Company.)

Keeler, E., Company, Catalogue, Cross Drum Water Tube Boilers. Williamsport, Pennsylvania, 1919. (From the Company.)

K-G Welding and Cutting Company, Catalogue. New York City, New York, 1919. (From the Company.)

Lansing Company, Catalogue No. 17C. Lansing, Michigan, 1919. (From the Company.)

Leland Stanford Junior University, "A Contribution to the Knowledge of the Coccidæ of Southwestern United States"; "Derivation of the Flora of Hawaii." Stanford University, California, 1919. (From the University.)

Liberty Manufacturing Company, Catalogue Z. Pittsburgh, Pennsylvania, 1919. (From the Company.)

Locomotive Dictionary and Cyclopedia, Fourth and Fifth Editions, 1916, 1919. New York City, New York, 1916, 1919. (From Mr. Alfred W. Gibbs.)

Locomotive Stoker Company, Catalogue No. 14-D. Pittsburgh, Pennsylvania, 1919. (From the Company.)

Locomotive Superheater Company, Bulletin T-2. New York City, New York, 1919. (From the Company.)

Lodge and Shipley Machine Tool Company, Catalogue of Lathes. Cincinnati, Ohio, no date. (From the Company.)

Machinery Company of America, Catalogue No. 31. Big Rapids, Michigan, no date. (From the Company.)

Macklem, John J., Scaffolding Company, Inc., Catalogue. Goshen, Indiana, no date. (From the Company.)

Manchester Municipal College of Technology, Journal of Technology. Manchester, England, 1918. (From the College.)

Mehl Machine Tool and Die Company, New Prospectus of Tool Service. Roselle, New Jersey, 1919. (From the Company.)

Michigan Public Domain Commission, Biennial Report, from July 1, 1916, to June 30, 1918. Lansing, Michigan, 1919. (From the Commission.)

Milwaukee Electric Crane and Manufacturing Company, Catalogue. Milwaukee, Wisconsin, no date. (From the Company.)

Minneapolis, St. Paul and Sault Ste. Marie Railway Company, Thirtieth Annual Report, 1918. Minneapolis, Minnesota, 1919. (From the Company.)

Molby Boiler Company, Inc., Catalogue of Molby Magazine Feed Down Draft Boilers. New York City, New York, 1917. (From the Company.)

Morgan Engineering Company, Bulletin No. 15. Alliance, Ohio, 1919. (From the Company.)

Morris, Herbert, Crane and Hoist Company, Ltd., Book No. 66. Niagara Falls, Canada, 1919. (From the Company.)

Murray Iron Works Company, Catalogue No. 85. Burlington, Iowa, 1919. (From the Company.)

New Jersey Foundry and Machine Company, Catalogue No. 99. New York City, New York, 1918. (From the Company.)

New South Wales Royal Society, Journal and Proceedings for 1917. Sydney, Australia, 1918. (From the Society.)

New York Conservation Commission, Annual Report, 1916. Albany, New York, 1918. (From the Commission.)

New York Public Service Commission, Annual Report, 1917. Albany, New York, 1918. (From the Commission.)

New Zealand Government Statistician, Statistics of the Domain, 1917. Wellington, New Zealand, 1918. (From the Government.)

North Eastern Construction Company, Catalogue of Giant Concrete Piles. New York City, New York, no date. (From the Company.)

Norwalk Iron Works Company, Catalogue of Air and Gas Compressors. South Norwalk, Connecticut, 1919. (From the Company.)

Novo Engine Company, Bulletin No. 11. Lansing, Michigan, no date. (From the Company.)

Ohio Engineering Society, Report of the Fortieth Annual Meeting. Columbus, Ohio, 1919. (From the Society.)

Ohlen, James, & Sons, Saw Manufacturing Company, Catalogue No. 74. Columbus, Ohio, 1919. (From the Company.)

Parks-Cramer Company, Catalogue, Fluid Heat Transmission. Boston, Massachusetts, 1919. (From the Company.)

Pittsburgh, Cincinnati, Chicago and St. Louis Railroad Company, Annual Report for the Year Ending December, 1918. Pittsburgh, Pennsylvania, 1919. (From the Company.)

Price Electric Company, Catalogue, The Price Indicating and Recording Pyrometers. Cleveland, Ohio, no date. (From the Company.)

Redwood Manufacturers' Company, Catalogue. San Francisco, California, 1919. (From the Company.)

Reed-Prentice Company, Bulletins of various types of lathes. Worcester, Massachusetts, no date. (From the Company.)

Reynolds Machine Company, Catalogue F. Massillon, Ohio, 1919. (From the Company.)

Rio de Janeiro Museu Nacional, Archivos Vol. xxi. Rio de Janeiro, 1918. (From the Museum.)

Shepard Lewis Company, Catalogue of the Jacklift Master Truck. Boston, Massachusetts, 1918. (From the Company.)

Simonds Manufacturing Company, Catalogue of Saw Steel Products. Fitchburg, Massachusetts, no date. (From the Company.)

Slocomb, J. T., Company, Catalogue and Measuring Book No. 16. Providence, Rhode Island, no date. (From the Company.)

Somerville Street Commissioner, Annual Report, 1918. Somerville, Massachusetts, 1919. (From the Commissioner.)

South Bend Lathe Works, Catalogue of Machine Shop Equipment for Vocational and Industrial Schools. South Bend, Indiana, 1918. (From the Works.)

Standard Spiral Pipe Works, Catalogue No. 7. Chicago, Illinois. no date. (From the Works.)

Steam Motors Company, Bulletin No. 5. Springfield, Massachusetts, 1919. (From the Company.)

Taunton, Massachusetts, Water Commissioners, Forty-third Annual Report, 1918. Taunton, 1919. (From the Commissioners.)

Terry Steam Turbine Company, Catalogue. Hartford, Connecticut, no date. (From the Company.)

Tide Water Oil Company, Catalogue of Fuel Oil. New York City, New York, 1919. (From the Company.)

Transmission Ball Bearing Company, Inc., Catalogue of Chapman Type Ball Bearings for Transmission. Buffalo, New York, no date. (From the Company.)

Truscon Steel Company, Catalogue of Steel Windows. Youngstown, Ohio, 1918. (From the Company.)

Trussed Concrete Steel Company, Catalogue of Canadian Steel Casements. Walkerville, Ontario, Canada, no date. (From the Company.)

Unit Railway Car Company, Catalogue, The Unit Car. Boston, Massachusetts, 1919. (From the Company.)

U. S. Naval Observatory, The American Ephemeris and Nautical Almanac for the Year 1921. Washington, District of Columbia, 1918. (From the Observatory.)

University of Minnesota, Bulletin No. 16. Minneapolis, Minnesota, 1919. (From the University.)

University of Nevada, Catalogue, 1918–1919, Including Announcements for 1919–1920. Reno, Nevada, 1919. (From the University.)

University of Pennsylvania, Catalogue, 1918–1919; Announcements, 1919–1920. Philadelphia, Pennsylvania, 1919. (From the University.)

University of Texas, Catalogue of the University and of The State School of Mines and Metallurgy, 1918–1919. Austin, Texas, 1919. (From the University.)

University of Vermont, Catalogue, 1918–1919. Burlington, Vermont, 1919. (From the University.)

Warner and Swasey Company, Catalogue of Turret Lathe Tools. Cleveland, Ohio, 1918. (From the Company.)

Wheeler, C. H., Manufacturing Company, Catalogue of Condensers and Auxiliaries. Philadelphia, Pennsylvania, 1919. (From the Company.)

Wilson Welder and Metals Company, Inc., Repair of the German Ships. New York City, New York, 1918. (From the Company.)

Wilton Tool and Manufacturing Company, Catalogue, Standardization by Wilton. Boston, Massachusetts, 1919. (From the Company.)

Wright-Austin Company, Catalogue of Steam Specialties. Detroit, Michigan, 1919. (From the Company.)

Yale and Towne Manufacturing Company, Semi-Centennial Souvenir, 1868–1918. (From the Company.)

CORRESPONDENCE.

BUREAU OF CONSTRUCTION AND REPAIR, NAVY DEPARTMENT.

Mr. R. B. Owens,
Secretary, Franklin Institute,
Philadelphia, Pa.

WASHINGTON, D. C., July 2, 1919.

MY DEAR SIR:

During my absence in Europe, there was received at my office the certificate of my election to Honorary Membership in The Franklin Institute, dated April 16, 1919. It has recently come to my attention that this certificate was not acknowledged, and I feel much mortification at the apparent neglect.

I beg to assure you and the members of the Institute of my deep appreciation of the honor conferred upon me.

Very sincerely,
(Signed) D. W. TAYLOR,
Rear Admiral,
Chief Constructor of the Navy.

JOHN J. CARTY,
195 Broadway,
NEW YORK.

Doctor R. B. Owens, Secretary,
The Franklin Institute, Philadelphia, Pa.

July 15, 1919.

DEAR DOCTOR OWENS:

I have just been discharged from the Army and am at work on affairs which have accumulated and which require my attention.

I have had a most gratifying surprise in receiving the diploma showing that I have been elected to be an Honorary Member of The Franklin Institute. This coming upon the other honors and courtesies which I have received at the hands of your society places me under so many obligations that I can never sufficiently express my feelings of high appreciation of The Franklin Institute and of its distinguished officers and members.

I assure you that I shall endeavor always to show that I am sensible of this great honor which has been conferred upon me.

Very sincerely yours,

JJC-AM (Signed) JOHN J. CARTY.

BOOK NOTICE.

THE REALITIES OF MODERN SCIENCE. An Introduction for the General Reader. By John Mills, Research Laboratories, Western Electric Co., Inc. 321 pages, contents, index, 44 illustrations, 12mo. New York, The Macmillan Company, 1919. Price, $2.50 net.

Several useful books for popularizing science have appeared of late years from American authors. Some of these have been condensed histories, others accounts of scientific procedures, principally chemical, expressed in non-technical language. They have been of much service in bringing to notice the value and the methods of modern science. The present work is more strictly scientific, but is well adapted to those who want information on some of the data of physics and chemistry, especially the border-land of these two sciences, physical chemistry, which has progressed at such a rapid rate in the last quarter-century.

The work begins with an exposition of the author's views as to the methods of the beginnings of knowledge, which, as might be expected, is the least satisfactory part of the book, as the information at hand on this point is very scanty, and in a book which deals so largely with exact scientific data, this presentation of the speculations—telescopic deductions from microscopic premises, as they have been termed—is a discord in the music. The author states among other things that monkeys probably use tools only in imitation of human beings, and that having no thumbs they cannot pick up articles. It is, however, stated on good authority that even in the wild state they throw sticks and stones at intruders, and they certainly have the ability to pick up even small objects. These questions are, however, of minor importance and do not in any way affect the merit of the work, which gives valuable information on some of the latest and most important phases of physical chemistry. Large space is devoted to the subjects of electrons, electrolytic dissociation and the various problems of molecular physics. The book will be a valuable contribution to the literature of the subject.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

The Realities of Modern Science: An Introduction for the General Reader, by John Mills. 327 pages, illustrations, 12mo. New York, The Macmillan Company, 1919. Price, $2.50.

Induction Coils in Theory and Practice: By Prof. F. E. Austin, E.E. 64 pages, illustrations, 8vo. Hanover, N. H. Author, 1919. Price, $1.

Illinois Department of Registration and Education, Division of the State Water Survey: Bulletin No. 15. Chemical and Biological Survey of the Waters of Illinois. Report for year ending December 31, 1917. 133 pages, map, 8vo. Urbana, State printers, no date.

University of Missouri, School of Mines and Metallurgy: Forty-eighth Annual Catalogue. 163 pages, 8vo. Rolla, University, 1919.

United States Geological Survey: Advance Statement of the Production of Copper in the United States in 1918, by B. S. Butler. 6 pages, 8vo. Washington, Government Printing Office, 1919.

U. S. Department of Labor, Working Conditions Service: How to Give Illustrated Lectures on Accident Prevention to Workmen. 13 pages, 8vo. Washington, Government Printing Office, 1919.

U. S. Bureau of Mines: Bulletin 151, Recovery of Gasoline from Natural Gas by Compression and Refrigeration, by W. P. Dykema. 123 pages, illustrations, plates, 8vo. Bulletin 165, Bibliography of Petroleum and Allied Substances in 1916, by E. H. Burroughs. 159 pages, 8vo. Bulletin 176, Recent Developments in the Absorption Process for Recovering Gasoline from Natural Gas, by W. P. Dykema. 90 pages, illustrations, plates, 8vo. Bulletin 179, Abstracts of Current Decisions on Mines and Mining, reported from September to December, 1918, by J. W. Thompson. 166 pages, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, March and April, 1919, compiled by Albert H. Fay, 2 pamphlets, 8vo. Technical paper 222, Method of Administering Leases on Iron-ore Deposits Belonging to the State of Minnesota, by J. R. Finlay. 40 pages, illustrations, 8vo. Technical paper 223, Cost Keeping for Small Metal Mines, by J. C. Pickering. 46 pages, diagrams, 8vo. Technical paper 224, Metal Mine Accidents in the United States During the Calendar Year 1917, compiled by Albert H. Fay. 80 pages, 8vo. Washington, Government Printing Office, 1918–1919.

The Production of Liberty Motor Parts at the Ford Plant. W. F. VERNER. (*The American Society of Mechanical Engineers,* Spring Meeting, June, 1919.)—The contract made with the United States Government called for 5000 motors and these were to be produced at the rate of 50 per day of eight hours. To do this, important developments in the methods of manufacture were brought about by the Production Department of the Ford Motor Company.

One of these was the method of producing cylinders from tubing. Six operations were necessary and the author describes them in detail. The methods employed to produce connecting-rod crankshaft bearings likewise resulted in a great saving of time. Twenty-one operations were found necessary for this work and a complete description of each is given. The method of installing bearings in the upper and lower halves of the Liberty motor crankcase, is also described.

CURRENT TOPICS.

The Alcohol Problem.—This note is not to discuss the question of the proportion of alcohol constituting a beverage as "intoxicating" nor the sociologic phases, but to point out that the practice of civilized countries of imposing heavy taxes on ethyl hydroxide is one of the most serious interferences with industrial development. Standing next to water as a general solvent, and having solvent powers on a large number of important substances not soluble in water, alcohol now finds extended use in the arts. Although governments have endeavored to release industrial alcohol from the tax burden, yet the only method so far generally adopted—that of incorporating with it ingredients that render it unfit for internal use—is by no means satisfactory. Apart from the uses of alcohol as a solvent, its adaptability as a fuel both directly and in the internal combustion engine opens up a great opportunity. It is of lower energy, weight for weight, than gasoline, but the fire-risk is so much lower and the odor unobjectionable.

The United States Government should institute a comprehensive research with a view of discovering cheap methods of producing alcohol and of devising means by which it can be sold freely for use in everything but beverages. The problems are complicated but they are not unsolvable. One question always presents itself to the law-maker, namely, the loss of revenue that will follow the removal of the tax. The restrictions that are imposed on the manufacture and sale of alcohol are due to the wide-spread opinion that taxes should be raised largely on luxuries, and alcohol has always been regarded as of this type, but apart from the changed conditions that will follow nation-wide prohibition, it surely is possible that taxes can be levied so as to be incident on the luxury and not on useful applications. The subject is too extensive to be discussed fully here, but it is well worth careful consideration by those interested in the advancement of the industries. H. L.

Ash Removal by Suction. (*Scientific American*, vol. cxx, No. 25, p. 661, June 21, 1919.)—What is virtually a large-sized vacuum cleaner has been delivered to a concern in New York City that specializes in cleaning ash bins of public buildings and large residences, and while the apparatus is experimental because it is now being tested out, the designers feel sure that it will prove to be not only practical and efficient, but will meet with the approval of the general public by minimizing the discomforts and dirt now met with in ash removal by the usual means of dumping the filled galvanized iron containers into open cart bodies.

The equipment is mounted on a five-ton chassis and is a large box compartment, resembling the conventional van, the doors and gates of which can be closed tightly. On the chassis is mounted a blower that is driven by the engine, and this is so adapted that ashes are drawn into the compartment from the ash pit, no matter what the angle, through a telescoping metal tube. The truck is driven to the curb at the nearest point to the ash pit, and the tube is extended into it. The ashes must be shoveled to the lower end of the tube and the suction carries them into the compartment on the truck.

The labor is limited to shoveling into the ash pit, or at least handling so the ashes can be drawn out by the blower, and there is no dust blown about outside. The time of loading the truck is much more rapid than would be possible were the work done manually, and this is of material importance when the time of trucks is considered as representing a substantial value. The prevention of dust will be approved by all sanitary departments of municipalities. The work of the apparatus is so satisfactory that adoption will soon be general, both for municipalities and for contractors.

Insect Helps Control Other Insects. (*U. S. Department of Agriculture, Bulletin No. 766.*)—An European parasitic fly that may become of far-reaching importance in the control of the gipsy moth and brown-tail moth and certain other serious pests of similar character is being multiplied from importations of this new insect enemy. A report of the work with the parasite—known as *Compsilura concinnata*—has just been made by entomologists of the United States Department of Agriculture.

This report shows that this parasite has reduced the damage done by the gipsy moth and the brown-tail moth in the New England States, where they were so abundant and destructive that they ate the leaves off enormous areas of forest and shade trees every year. It has been found that *Compsilura* also aids in the control of other insect pests.

The white-marked tussock moth, a serious pest in the New England States a few years ago, has practically disappeared since *Compsilura* has become established. The cabbage worm, still a serious pest, has been lessened in some sections. Celery worms are not as common as formerly, and the fall webworm is scarcely noticed in the Northeastern States now.

The entomologists do not claim that this parasite is the sole cause of this reduction, but it has proved an important natural enemy to all of them. It is thought that *Compsilura* may become one of the most important economic parasites in this country.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA